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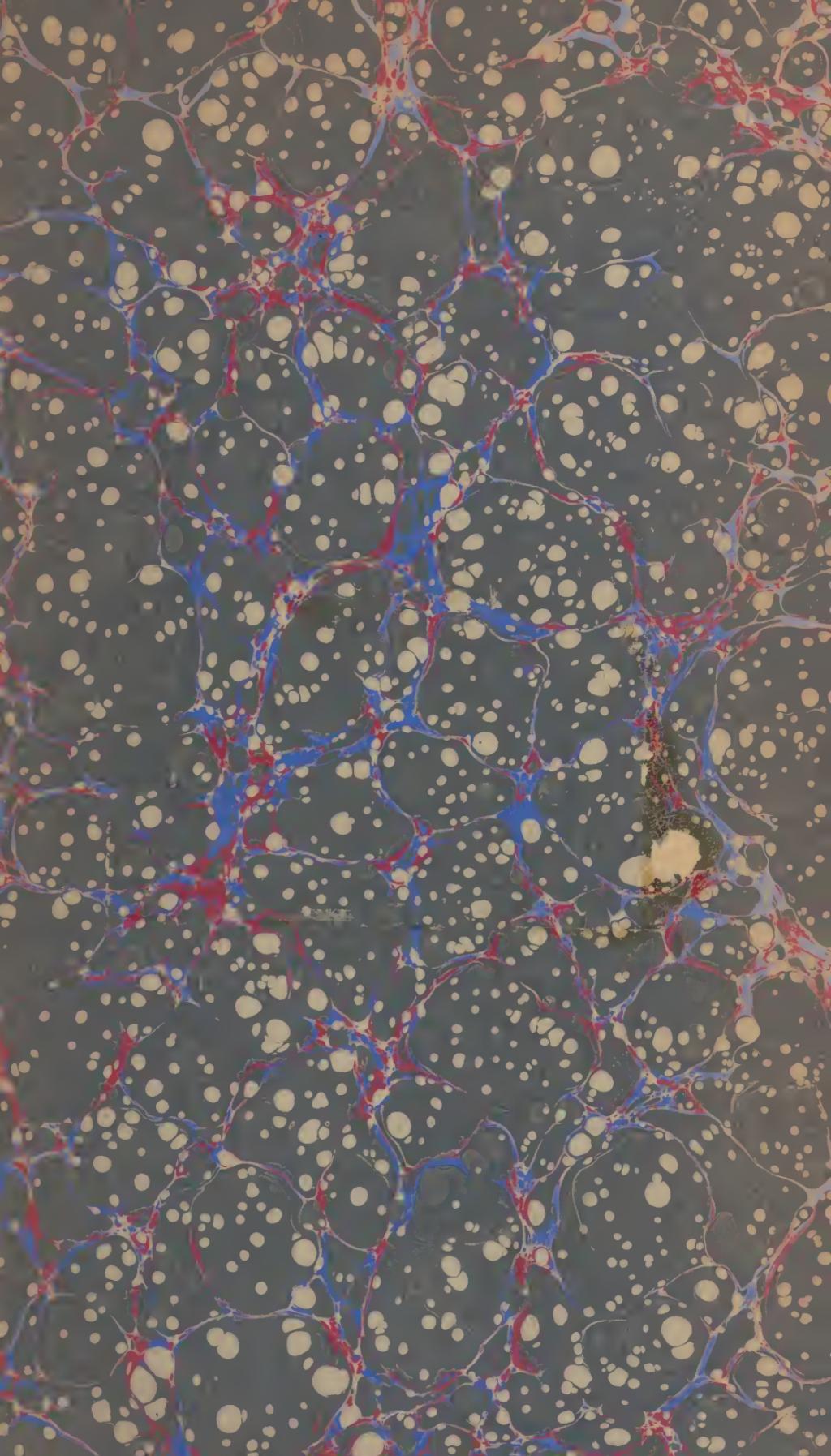
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PARIS UNIVERSAL EXPOSITION, 1867.

REPORTS OF THE UNITED STATES COMMISSIONERS.

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THE PROGRESS AND CONDITION 497

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OF

SEVERAL DEPARTMENTS

OF

INDUSTRIAL CHEMISTRY.

BY

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UNITED STATES COMMISSIONER.



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INDUSTRIAL CHEMISTRY.

INTRODUCTION.

No department of the Exposition of 1867 is more pre-eminent in importance than Class 44, embracing chemical products and chemical processes. In fact, industrial chemistry links itself with every modern art in such an intimate manner, that were we to take away the influence and results of chemistry it would be almost like taking away the laws of gravitation from the universe. Industrial chaos would result in one case, as material chaos would in the latter. The miner, the metallurgist, the machinist, the weaver, the paper maker, the painter, the glass maker, the fine arts, all draw from the rich storehouse of chemistry. To these we must add the new arts born directly from the same source, viz: photography, galvanoplasty, gilding and silvering metals, dyeing with new colors obtained from coal, vulcanized India-rubber, stearine candles, sugar from starch and wood, &c.

No one can paint in too vivid colors the sum of indebtedness the civilized world is already under to the chemist, and no enthusiast can transcend in his wildest speculations what we are yet to realize. The chemical arts in their strictest sense do not simply aid the other arts, but they keep in activity a vast amount of capital, and consequently give employment to a large number of individuals, skilled and unskilled. In France alone the annual value of chemical products is \$250,000,000, of which \$125,000,000 represent the articles of sulphuric acid, soda, soap, India-rubber, and candles. Of chemical products, France exports \$20,000,000 worth, the remainder being consumed at home in giving activity to other industries whose products are largely exported in the form of woollen, cotton, and silk stuffs, &c.

The above statement represents the activity of industrial chemistry in but one country; yet every part of the civilized world is more or less engaged in the manufacture of chemicals, as the extensive and beautiful collections in the present Exposition demonstrate. These collections are placed there by 1,548 exhibitors, divided as follows: France, 358; England, 108; Belgium, 85; Prussia, 125; Austria, 150; other parts of Germany 55; Switzerland, 37; Spain, 57; Portugal, 16; Sweden, 14; Norway, 25; Russia, 71; Italy, 200; America, 30; Holland, 40; Denmark, 10; Algiers, 44; Greece, 25; Turkey, 99; Egypt, 2; China, 2; Brazil, 98; other parts of South America, 5.

In addition to the number of chemical works it is well to notice their size, for in many of them the operations are conducted on a gigantic

scale; as, for instance, in the works of Messrs. Allinson & Sons, at Newcastle-on-Tyne, which, although not the largest, consumes *weekly* the following enumerated materials, in tons: coal, 2,250; pyrites, 350; nitrate of soda, 10; chalk, 900; salt, 450; manganese, 100; lime, 125.

The weekly production is: 450 tons crystallized soda, 150 tons refined alkali; 100 tons bicarbonate soda; 30 tons of caustic soda; and 110 tons chloride of lime—in all, 830 tons chemical products; enough to freight a good-sized ship.

It is not the province of this report to detail the general character of the articles exposed by the different exhibitors, except so far as this or that article may possess some special merit.

Industrial chemistry has its greatest expansion and widest range of production in France and England, especially as regards what are called the staple articles; but in the manufacture of many of the less abundant products Germany is not surpassed, and in the last five or ten years has taken rapid strides towards competing successfully with France and England in the manufacture of almost all substances.

Of course, a necessarily hurried and somewhat confused examination of the great variety of products found in the Exposition must interfere with a very satisfactory criticism in many points; and as to the processes, a knowledge of them could only be obtained from more or less imperfect descriptions by the exhibitors, except when time afforded an opportunity to visit the factories, and where the owners were willing to be communicative, and allowed free access to all the apparatus when in operation.

The most striking progress, since 1862, is the invention of new colors from coal-tar, (toluidine and methylaniline,) better known as aniline colors, but especially in the improvement in the quality, and a wonderful diminution in the cost of those previously known; the transformation of naphthaline into benzoic acid; the manufacture on a large scale of fluosilicic acid, destined to play an important part in the manufacture of soda and potash; and finally, other inventions and improvements which will be alluded to in detail in this report. It is proper, however, to state that the progress of the chemical arts during the past five years has not been so remarkable for any great discovery of new processes as it has been in perfecting those which had already been employed, so as to furnish more abundant and cheaper products.

In this report the labors of the scientific men with whom I had the good fortune to be associated will be used whenever required, and without reserve, when it is conceived necessary to furnish correct and useful information to the American public; and I take this opportunity to acknowledge my indebtedness to the kindness of my associates on juries, and in the grand council, among whom I would enumerate the French and continental chemists MM. Ballard, Dumas, Liebig, St. Claire Deville, Bouterelle, Kuhlmann, Daubrée, Hofmann, and others.

The natural subdivisions of the products of industrial chemistry bring into the foreground the acids and the alkalies. As they constitute the substructure of the chemical arts, and as of this substructure sulphuric acid is the corner stone, this acid and its manufacture will be viewed in all its bearings upon the chemistry of the Great Exposition of 1867.

INDUSTRIAL CHEMISTRY.

CHAPTER I.

THE MANUFACTURE OF SULPHURIC ACID.

IMPORTANCE OF THIS ACID TO THE USEFUL ARTS—VARIOUS METHODS PROPOSED TO AVOID THE USE OF CHAMBERS—SUBSTANCES EMPLOYED IN THE MANUFACTURE—SULPHUR, EXHIBITION OF, AND PRINCIPAL SOURCES—SULPHUR FROM SODA-WASTE—BLACK-ASH, MOND'S PROCESS—SULPHUR FROM COAL GAS—FROM PYRITES—METHODS AND PROCESSES OF MANUFACTURE—SULPHUR FURNACES—LEAD CHAMBERS—PYRITES FURNACES—GERSTENHOFFER'S FURNACE—UTILIZATION OF THE RESIDUE FROM THE PYRITES FURNACE—COMBUSTION OF PYRITES COMPARED WITH THAT OF SULPHUR—OXIDATION OF SULPHURIC ACID—EFFORTS TO PRODUCE SULPHURIC ACID WITHOUT THE AGENCY OF NITRIC ACID—GAY LUSSAC'S PROCESS—PURIFICATION OF THE ACID FROM ARSENIC—CONCENTRATION OF SULPHURIC ACID—PLATINUM STILLS—DESCRIPTION IN DETAIL OF THE CONSTRUCTION OF SULPHURIC ACID WORKS.

1.—APPLICATIONS AND PROGRESS OF THE MANUFACTURE.

When we glance over the chemical products that influence to the greatest extent the useful arts of society, we find them among the acids and alkalies; for by the chemical reaction of these compounds, furnished by nature or art, the manufacturing and domestic arts generally obtain a multitude of useful compounds. But of all substances that have made their imprint on the modern progress of the arts, there is no one approaching sulphuric acid in importance, produced as it is from the cheapest materials furnished by nature, and of which there seems to be inexhaustible supplies. Glass making, soap making, bleaching, calico printing, dyeing, &c., are all large debtors to sulphuric acid. It is said that the consumption of sulphuric acid in any country will show, with that of iron, its industrial activity. The low price of the acid is one of its great merits; the ordinary form known as oil of vitriol, being the most concentrated form in ordinary use, is now made in France at a cost of about one and a quarter cent per pound, and in England for a shade less; in this country ill-advised legislation makes a much higher and fluctuating price.

No material change has taken place in the last ten years or more in the manufacture of sulphuric acid. The well-known method of converting sulphur into sulphurous acid, and completing the oxidation of it by the oxygen of the air, aided by one of the oxygen compounds of nitrogen, is still the predominant method, and, in fact, all of this acid that is manufactured, except the small quantity made by distilling copperas, and called Nordhausen acid, is made by this process.

It will not, however, be unprofitable to the readers of this report to enumerate some of the various attempts made in the last twenty years to supplant the present method in lead chambers. Lealand and Deacon,

in 1854, suggested the use of chambers made of stone, or earthenware. Simon, in 1860, proposed vulcanized gutta-percha, but on trial this substance was found more destructible than lead. Peter Ward, in 1862, proposed a series of glass sheets to increase the surface and hasten the reaction; that, however, had been used before, and as the formation of sulphuric acid is not dependent on surface action, it is of no advantage. Philips and Kuhlmann, as far back as 1838, proposed the use of heated air, and sulphurous acid passed over spongy platinum, but this has been almost forgotten. Fouché and Lepelletier, in 1850, employed a series of large Woolfe bottles instead of the lead chambers, at Javelle near Paris, but this has been long since abandoned. Kuhlmann proposed to pass a mixture of sulphide of hydrogen, obtained by proper means from soda waste, through nitric acid in stone-ware bottles, but the method was never put in practice. Petrie, in 1860, applied a system of stone-ware columns, filled with pebbles, through which currents of nitric acid and sulphurous acid in proper proportions were passed; but this has not been successfully applied. Several years ago Persoz accomplished the oxidation "by passing the sulphurous acid gas through nitric acid, diluted with from four to six volumes of water, and heating to 212° F., or through a mixture of nitric acid, or a nitrate with hydrochloric acid. The reaction takes place in a comparatively small vessel of suitable material; the gas arising from the deoxidation of the nitric acid is reconverted into nitrous acid by air and water. Theoretically, it works without a loss of nitric acid; nevertheless the process has never been adopted in practice, possibly from want of suitable material to withstand the combined action of the two strong acids."

II.—SUBSTANCES EMPLOYED IN THE MANUFACTURE OF SULPHURIC ACID.

SULPHUR.

There was a most beautiful display of specimens of sulphur from the south of Italy and from Sicily; and these countries furnish all the sulphur that is employed in the arts and in agriculture, except some little that is employed for domestic use in countries producing it, of which notice will be taken a little further on. While we now obtain the larger proportion of sulphuric acid made in Europe from pyrites, it is very much to be desired that new and abundant supplies of sulphur may be found, for the acid made from this substance directly is purer, and the apparatus required less expensive, than when pyrites is used. Besides the sulphur exhibited from southern Italy and Sicily, there were specimens from Apt, in France, which locality furnishes a poor sulphur mineral. Also in the neighborhood of Constantine, in Algiers, there is native sulphur. In central Italy, near Bologna, there is a vein of sulphur ore about fifteen miles long, but the mineral is not rich, and is necessarily taken from a great depth, sometimes over 800 feet. About 12,000 tons are produced here annually, which is almost entirely consumed in

the neighboring country for diseases of the vine. From the Papal States there were also specimens of sulphur, but the quantity produced there is very small, not exceeding 500 tons. The Spanish specimens come from Mureia and neighboring localities, where there are some fine mines of sulphur. Besides the above, there were specimens on exhibition from Galicia, near Cracovy, from Corinthia, in Hungary, from the Grecian island of Milo, from Tripoli, Isthmus of Suez, on the borders of the Red sea, province of Rio Grande, in the north of Brazil; but, as already stated, it is from Sicily that we obtain the great bulk of sulphur used in the arts. In this island the strata of sulphur extends over a length of about 170 miles, superimposed one on the other to a depth of from three to 25 feet and containing about 30 per cent. of sulphur. The mines are owned by various influential individuals, who, by restricting the supply and by rude and imperfect mining, keep up the price to the present standard. There have been as many as 1,000 mines opened, but at the present time not more than one-half are worked.

The manner of obtaining the sulphur has been frequently described, and was formerly of a very crude character. The method now in most frequent use is that of Tucci, the inspector of mines of Catanisette and Catania. It is by means of a species of furnace called *calcarones*, by which very large amounts of the mineral can be operated upon at once. These *calcarones* are simply circular furnaces of a conical form, having an inclination of from 20° to 45° according to the nature of the gangue, (which is calcareous or of gypsum,) so that the viscous sulphur can descend and run off at the bottom. The walls of the furnace are about one foot thick and ten feet deep and made of a capacity to hold more than 1,000 cubic yards of the ore; at the bottom of the furnace there is a hole to run off the melted sulphur, being the outlet of a channel coming from the interior of the furnace, which channel is continued for a little distance outside of the furnace, and is branched and arched over by laying masses of the mineral so as to form little tunnels leading to a reservoir.

The furnace is charged by putting large lumps in the middle, and then smaller fragments on the outside, and finally covering all over with previously exhausted ore. Around the upper part of the furnace are several small chimneys going down a foot or two; by these the furnaces are kindled at the top and air is supplied by percolation from above. One operation requires about twelve or fourteen days. The sulphur which has been collected in the reservoirs is cast into molds. The furnace requires twelve or fourteen days to cool down, when it is cleaned out and recharged; and this operation is repeated so long as the furnace lasts.

There are recent processes of separation proposed by Fangré, and by Emile and Pierre Thomas, depending on heat, but they deserve no special notice.

The most novel method is that of Deiss, viz., to dissolve out the sul-

phur by sulphuret of carbon, and an apparatus has been erected to extract by his process several tons of sulphur daily, but practical difficulties still exist and prevent it from becoming a complete success.

The quantity of sulphur produced in Sicily has gradually increased from 46,000 tons in 1832, to 300,000 tons at this time, worth from \$22 to \$24 a ton at the port of exportation. This increased consumption of sulphur, in spite of the diminished use of it in the chemical arts, (for it will be shown a little further on that pyrites to the amount of 800,000 tons, representing 250,000 tons of sulphur, has taken its place,) is due to the very large and increasing amount used for preventing diseases of the vine—diseases that have been almost exterminated by its use; but its use is kept up, as it is considered of great importance to give the vineyards an annual treatment of sulphur. If, however, sulphur should fall in price a little below what it is now, it would again come into general use in the manufacture of sulphuric acid.

SULPHUR FROM SODA-WASTE.

In the German section were shown the results obtained by the process of M. Mond, a chemist, of Utrecht, by which he extracts sulphur from soda-waste. The soda-waste has ever been a great nuisance, as well as a great loss in the manufacture of soda by Leblanc's process. It has become so great a nuisance in many of the large factories, that stringent sanitary laws have been passed concerning the disposal of it; and in some places, where it has been scattered over large surfaces, birds have been known to be asphyxiated while flying over it, and to fall to the ground. A large amount of sulphur is thrown away in this waste, so that for forty or fifty years chemists have endeavored to solve the problem of turning it to some account. The prospects now are that it can be made to yield up much of its sulphur, and the residue to furnish a valuable fertilizing agent, instead of a pestilential nuisance. Some idea may be formed of the abundance of this waste when it is stated that for every ton of alkali manufactured one and a half ton of dry waste is produced, furnishing the accumulations referred to, that during moist and rainy weather emit sulphuretted hydrogen gas, and in solution, poisoning waters of all kinds in the neighborhood. Besides the process of Mond there are two others brought forward, one by M. Schaffner, and the other by P. W. Hoffman; and seven works exhibit sulphur prepared by one or other of these processes. All the processes are based on the same principle—the conversion of the insoluble sulphide of calcium in the waste into soluble compounds, by bringing it freely in contact with air, in order to oxidize it; lixiviation of the oxidized mass, and precipitation of sulphur in these liquids by a strong acid, as muriatic acid.

BLACK-ASH—MOND'S PROCESS FOR OBTAINING SULPHUR.

I propose giving a tolerably full account of Mond's process, as described by himself, in using the waste from the black-ash generally employed in

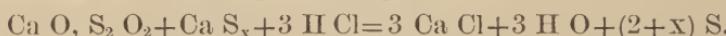
England, and which allows of more rapid operation than the more compact waste of most continental works.

In place of the set of four vats generally in use for lixiviating black-ash, he employs a set of ten or twelve. All of these are connected by pipes in the usual way, so that the soda liquor runs from the bottom of one vat to the top of the next one, and by special pipes and taps which allow the sulphur liquor to run out of the bottom of each vat to the top of any other vat in the set. Besides this, they are provided with extra taps and shoots to convey the sulphur liquor to wells or settlers. The lower parts of all the vats are connected with a fan, (capable of producing a pressure of about seven inches of water,) by pipes furnished with dampers, which regulate the quantity of air passing through.

A noiseless fan of Schiele's construction, twenty inches diameter, price \$50, propels a sufficient quantity of air for the treatment of the waste resulting from 100 tons of salt cake per week. Four of the vats are always filled with black-ash in the course of lixiviation; the other six or eight with waste to be treated according to the invention. As soon as the black-ash is completely spent, and the weak liquor is well drained off, the connection with the fan is opened. The waste soon begins to heat, the temperature gradually rising above 200° F., and gives off quantities of steam, becoming greenish, and afterwards yellow on top, gets more and more dry, and would take fire if the air was passed through long enough. The time for discontinuing the passing of air, so as to have the best results, must be ascertained in each establishment by experiments, and varies according as much or little hyposulphite in the hydrosulphide and bisulphide of calcium are formed, which are afterwards oxidized into hyposulphite. A part of the hyposulphite is again decomposed into sulphur and sulphite, which is very insoluble, and cannot be extracted by lixiviation. Carrying the oxidation too far would therefore entail a serious loss. On an average the time of exposure will be limited to between twelve and twenty-four hours. The waste is now lixiviated systematically with cold water, the weaker liquors passing from one vat to the next one in course of lixiviation, so as to obtain only strong liquors, which operation can be easily performed in six to eight hours. When this lixiviation is finished, air is again passed through the waste in exactly the same way as before; the waste is again lixiviated, and the same treatment is repeated a third time. The vat is then ready to be cast, and is again filled with black-ash. When the operations have been well conducted, sulphur equal to about 12 per cent. of the weight of the salt cakes used in making black-ash is obtained in solution from the waste. The waste contains only traces of sulphide of calcium, and is principally composed of carbonate of lime, sulphite and sulphate of lime, which, far from being noxious, make the waste, on the contrary, a valuable manure. In separating the sulphur from the liquors thus obtained, by adding muriatic acid, I met with much more difficulty than I had anticipated from apparently such a reaction.

The oxidation of the waste is regulated so as to obtain a liquor, which contains as nearly as possible to every equivalent of hyposulphite two equivalents of sulphide. This liquor is decomposed by first adding to a certain small quantity of acid an excess of liquor, until there is a trace of sulphide in the mixture; then a quantity of acid sufficient to neutralize the whole of the calcium is poured in; a new quantity of liquor equivalent to this last quantity of acid is added, and then acid again and liquor again, and so on until the vessel is nearly filled. To the last liquor only one-half of the required acid is added, and steam introduced until the liquid shows a temperature of about 140° F. Practically speaking, the liquor and acid are poured at the same time into the decomposing vessel in nearly equivalent proportions, the workmen taking care to keep a small excess of liquor up to the end of the operation. This part of the process is carried on in covered wooden tanks connected with a chimney in order to carry off any sulphuretted hydrogen which may be evolved by mistake of the workman. If properly carried out there should be, however, no appreciable quantity of that gas evolved.

The practical result of this mode of working is simply precipitation of nearly the whole of the sulphur in a pure state.



The details of the reaction are, however, very complicated, almost all the different acids of sulphur being probably formed during the process.

In practice, about 90 per cent. of the muriatic acid, calculated according to the above-described method, is required to thus effect the complete decomposition of a well-proportioned liquor. If it contains more hyposulphite than above indicated, less acid is, of course, to be used. About 90 per cent. of the sulphur contained in the liquor is precipitated in an almost pure state, and settles exceedingly well within two hours. The supernatant clear solution of chloride of calcium is then drawn off, and another operation directly commenced in the same vessel as soon as a sufficient quantity of sulphur is collected in it, which will depend on the size of the vessel and on the strength of the liquor, ranging from four per cent. to seven per cent. of sulphur; it is drawn out by means of a door at the lower part of the vessel into a wooden tank with a double floor, where the chloride of calcium is washed out by water, and the sulphur is then simply melted down in an iron pot. The product thus obtained contains only from one-tenth of one per cent. to one per cent. of impurities, and is thus by far superior to any sort of brimstone in the market, though it has sometimes a rather darker color, caused by traces of sulphide of iron, or a little coal dust, which latter may have been suspended in the muriatic acid.

The total yield of sulphur obtained by the process amounts thus to 10 or 11 per cent. of the weight of the salt-cake used in making black-ash, or to about one-half of the sulphur therein contained, and to about 60 per cent. of the sulphur contained in the waste. It is still hoped,

however, to considerably increase this quantity after some more years of experience.

The cost of production is inconsiderable. In the different continental and English works, where the process has now been working for years, the expense for wages, fuel, and maintenance amounts only to five dollars per ton of sulphur, and the outlay for the apparatus will be more than covered by the net profits of the first year. An establishment making three tons can save at least \$2,000.

SULPHUR FROM COAL GAS.

In the manufacture of gas from coal, sulphide of hydrogen is one of the products from which the gas must be purified; and, for several years, what is known as the oxide of iron process has been adopted in large towns. This process consists in passing the gas through layers of peroxide of iron, mixed with some inert material to give it the necessary mechanical subdivision. The peroxide of iron is reduced to protoxide of iron, and the sulphur is precipitated in the mass, remaining uncombined. Exposure to air reconverts the protoxide into peroxide of iron without altering the sulphur contained in it; and this revived peroxide is used a second, third, and fourth time, in fact until the accumulated sulphur interferes with its rapid action, when it is replaced by fresh material. After repeated use this oxide of iron often contains as much as 40 per cent. of sulphur. Some sulphuric acid factories employ this residue thus charged with free sulphur, and manufacture sulphuric acid from it after certain cyanides are extracted from it by other factories. The amount of sulphur that could be thus furnished annually is very great, estimating the sulphur in coal as one per cent., when its average is actually much greater. In London and its suburbs alone the gas produced annually would furnish 15,000 tons, equal to 30,600 tons of sulphuric acid. M. Lawes, near London, uses 2,180 tons of this residue, each ton furnishing one and a quarter ton of sulphuric acid.

SULPHUR FROM CALIFORNIA.

To the northeast of Borax lake, in California, and about one mile from it on the borders of Clear lake, is a large deposit of sulphur, where solfataric action is still apparent. The amount of sulphur which has been deposited in this place is very large, covering an area of several acres, and extending to a depth not yet ascertained. From six to eight tons of this sulphur are refined daily, and are used in the manufacture of sulphuric acid, gunpowder, &c. A small quantity of cinnabar is associated with this sulphur. There is another large deposit two miles from this locality, at Chalk mountain, and still another at Sulphur Springs further east; but neither of them contain cinnabar. These and other localities of sulphur in California were represented in the collection sent from California by the commissioner.

PYRITES.

The manufacture of sulphuric acid from pyrites is probably the most important improvement made in manufacturing chemistry since the production of carbonate of soda from sulphate of soda, by Leblanc; and although it has been in operation for many years, it is instructive to review it in connection, together with the development of industrial chemistry in the past few years; for hardly fifteen or twenty years have elapsed since all sulphuric acid was manufactured from Sicilian sulphur, with but one or two insignificant exceptions, while now there is not more than one-tenth of this acid made directly from sulphur.

While the use of iron pyrites in the manufacture of sulphuric acid dates back prior to 1830, it was not until 1838 that the short-sighted policy of the king of Naples, granting the monopoly of Sicilian sulphur to Messrs. Taix & Co., of Marseilles, that its use was fairly established, for the price of sulphur rose in England from \$25 to \$70 dollars a ton, and in twelve months from that time, in England alone, not less than fifteen patents were granted for the manufacture of sulphuric acid from pyrites. And although the monopoly was soon withdrawn, by the persuasion of English vessels of war and the diplomacy of other governments, the pyrites had secured a firm footing in supplanting sulphur in the manufacture of sulphuric acid; and since then its use has rapidly increased, giving a wholesome lesson to governments to exercise great caution in granting monopolies and in legislating so as not to thwart industries based upon a science that draws colors rivaling the tints of the rainbow from coal, and that is not to be confined in the manner and method of its creations so long as the elements in one shape or another are at its command.

Since the first production of sulphuric acid from pyrites the establishment of Fahlun, in Sweden, has employed this process altogether, pyrites being very abundant in that locality. This example was followed by Perret, of Chassy, France, where the pyrites contains from three to four per cent. of copper, which metal can only be extracted by desulphurizing the ore. From the mines of this locality 70,000 tons of pyrites are burnt and exported annually, and the various lead chambers here for making sulphuric acid have a capacity of about 1,600,000 cubic feet. This process is carried on in all parts of France, whether the pyrites contains copper or not, and Sicilian sulphur is only employed for special purposes in France and England.

In the middle of France the pyrites of d'Alais is principally employed, it being very abundant. In the north of France the Belgian pyrites is used. In England the Irish pyrites is sometimes employed, although containing not more than 30 per cent. of sulphur; but most of the manufacturers use the pyrites coming from Huelva, in Portugal, containing 45 to 50 per cent. of sulphur, where the deposits of pyrites are remarkable for their great extent, extending into Andalnsia, in Spain.

One of the mines that is worked in the province of Alentejo, in Portugal, has a deposit of massive pyrites nearly a half a mile long by two hundred and fifty feet across the widest part, and contains from two and a half to four per cent. of copper.

Pyrites is frequently arsenical, and as the sulphuric acid produced from it contains arsenious acid, it is unfit for many purposes, especially where it is employed in the manufacture of products of domestic economy, such as acetic, citric, and tartaric acids, and also in some of the industrial arts, and in cleansing the surface of metals for alloying them with tin or other metal. In these cases acid made from sulphur is to be used, or the pyrites acid is to be purified by means of sulphide of barium or by sulphide of hydrogen, when the acid thus treated is equal in purity to any other.

It is not to be supposed, however, that sulphur is henceforth to be excluded from the manufacture of sulphuric acid; on the contrary, it is more than probable that many factories will return to its use, as the sulphur in Sicily is almost exhaustless, and if ever the country becomes opened to the world by good and numerous roads, the price of sulphur must diminish; and the diminution required is very small to bring it again into more common use among the acid manufacturers of the world. The factories in Belgium, in the north of France, and some in other parts of that country, those in Germany, and a number in England, will find it profitable in almost any state of the case to continue the use of pyrites.

III.—METHODS AND PROCESSES OF MANUFACTURE.

BURNING THE SULPHUR—SULPHUR FURNACES.

It is not necessary to dwell upon this part of the subject, from the fact that there are so many various ways, each said to be excellent, for securing the combustion of the sulphur used for the manufacture of acid. Reference will be made simply to the principles involved in the best form of furnace. It is better to have one large than many small furnaces, (called the sulphur furnace,) and to have all the sulphur used for one day's combustion (say from one to four tons) introduced at one charge, and to have just sufficient air admitted to keep up the combustion without heating the mass too much, as thereby more sulphur is volatilized. The vapor from the sulphur furnace should pass to the combustion furnace, in which sufficient air is admitted to complete the combustion, allowing an excess of about two to three per cent. of oxygen. From the combustion furnace the sulphurous acid therein formed passes to the nitre oven, and from thence the mixed vapors pass into the lead chambers.

LEAD CHAMBERS.

Too great care cannot be given to the construction and working of the sulphuric acid chambers. The plumbers should be required to distribute

the straps uniformly, and not to have too great a strain on any one, as the lead of the chamber is often torn by the neglect of this; the chambers should be kept in perfect repair and free from holes, or otherwise the sulphurous acid is lost in greater or less quantity. Where repairs are neglected, the practical yield with the same amount of material may range in three years from 82 to 68 per cent. of product.

The sulphur is not often lost from an incomplete conversion of the sulphurous into sulphuric acid by too little steam, too much air, and an insufficient quantity of nitre, but more frequently from too little chamber space to the amount of sulphur burnt. In connection with lead chambers it is interesting to refer to the chambers of Kuhlmann, of Lille, that prince of industrial chemists, the neatness and cleanliness of whose immense works is only excelled by the skill exercised and the purity of the articles manufactured. His chambers have a capacity of about 53,000 cubic feet. There are six different compartments, the first a small one, which is a cooler and purifier; the second a small denitrifying chamber; the third a small nitrification chamber; the fourth a large chamber; and fifth and sixth small chambers, called the tail chambers. Nitric acid is employed for oxidizing, which is introduced into the third chamber, in a small stream divided into a spray by convenient arrangements. The circulation of the liquid acid proceeds from chamber five, which opens into chamber six; from this it flows into the large chamber, which receives also the acid from the nitrification chamber; the acid collected in the large chamber ultimately passes into the denitrification chamber before it reaches the evaporating pans; to secure a perfectly regular distribution of steam through the whole system, the lead pipes which deliver it into the chambers are provided with platinum nozzles, which prevent the orifices of the tubes from gradually collapsing.

Some of the chambers in Lancashire have over 100,000 cubic feet capacity; and, as a general rule, the larger the chamber the better the proportional yield. One of the most important problems in the improvement of sulphuric acid chambers is to produce chambers of small dimensions capable of producing the greatest amount of sulphuric acid free from arsenic. To diminish the amount of capital in establishing a lead chamber for this acid, multiplies their number, and brings an article requiring a certain amount of useless water and bulky receivers nearer to the consumers, diminishing the cost of transportation.

At Bordeaux, Fournet has established the manufacture of sulphuric acid in a manner that deserves special attention, as it looks toward this economy just referred to. By means of apparatus skillfully arranged, in which the gas is made to circulate more than once in pipes filled with coke, so as to bring about an intimate mixture, and then passing it into a small lead chamber, Fournet has succeeded, with a chamber of only 12,000 cubic feet, in burning 1,000 pounds of sulphur a day and obtaining a yield of three tons of sulphuric acid, an amount nearly equal to the theoretical yield.

FURNACES FOR BURNING PYRITES.

There is nothing specially new in the present construction of furnaces used for burning pyrites, but as these are scarcely used in America, but perhaps can be with advantage, it is well to refer to them here.

At first fuel was mixed with the pyrites to keep up the combustion, but this was soon abandoned, and it is found that pyrites in burning furnishes all the heat necessary to continue the combustion. The beds of pyrites are made quite thick; at Javelle, France, they are made over three feet thick, and the doors of the furnace are luted. The combustion goes on very slowly, so that forty-eight hours are required for the upper layer of the pyrites to descend to the grate-bars. In this way most complete combustion is procured, and hardly two or three per cent. of sulphur remain in the residue. However, to accomplish this complete combustion, the pyrites must be in lumps; but as the pyrites is obtained about 10 per cent. of it is more or less pulverized, constituting one of the annoyances in this method of making sulphuric acid.

Various methods and furnaces are in use for the combustion of this fine pyrites, and they accomplish the result more or less perfectly.

The furnace of Spence, used almost universally at Manchester, is probably the best for this purpose. This furnace is a very long one, from forty to fifty feet long by six feet wide, and inclined about fifteen inches downwards. The floor of the furnace is of large flat tiles, and is heated from below by a lateral furnace three or four feet in advance of the lowest part. The fine pyrites is introduced by an opening in the top of the furnace, and is spread by means of rakes introduced through a lateral door only opened during the raking, and when it is necessary, by skillful movement, to push forward the pyrites to the lower part of the furnace. After being allowed to cool, it is drawn out of the furnace, at the front part, through an opening that supplies the requisite quantity of air by adjustment.

The roasting lasts about twenty-four hours—the furnace having twelve doors on the side, and two hours being allowed to the pyrites between each door before it is pushed forward. It is said that the fine pyrites can be made to give up all but two or three per cent. of its sulphur, a result not far from what is realized with that in lumps; and when it is remembered that this fine pyrites bears a less price than that in lumps, these results are certainly of vast importance to the large factories. Kuhlmann, in his process, mixes the fine pyrites with clay, and makes small balls or cakes, that, after drying, are used in the same furnace in which he burns the lump pyrites. Five per cent. of clay is sufficient to mix with the fine pyrites to form the little balls, and they can be made at a cost of about forty cents a ton in France.

The furnace that Michael Perret has introduced for burning fine pyrites in several establishments in France is highly spoken of. Instead of using the long furnace of Spence, he divides the furnace into a num-

ber of shelves, with large fire tiles, six centimeters thick and ten centimeters apart, and so placed in the masonry that the hot air and gases proceeding directly from the pyrites in lump, burning in the ordinary furnace, circulate back and forth (ascending all the time) over these shelves, on which the fine pyrites is spread to a depth of three centimeters. We may have ten or more of these shelves, until the furnace becomes inconveniently high. The operation lasts thirty-six hours, and each furnace can burn one ton of fine pyrites. This system is said to require one per cent. more of nitre in the subsequent operations.

FURNACE OF GERSTENHOFFER.

We cannot omit giving a passing notice of the furnace of Gerstenhoffer, of Freiberg, which is employed by the Vieille Montagne Company of France, and also at Swansea, in Wales. At the last-named place it is used for desulphurizing copper ores containing 30 per cent. of sulphur, and from which they are now collecting the sulphurous acid and making sulphuric acid.

The furnace is composed of a quadrangular tower eighty centimeters square and six meters high, closed at the top, except a long, narrow opening extending from one side to the other. Above this opening is placed a hopper of the same length, provided with two feed-rollers at the bottom, the movement of which feeds the furnace with pulverized pyrites. This pyrites, as it enters the furnace, falls on a triangular prism or cross-bar of brick fastened horizontally to the walls of the furnace, with its base uppermost. The powder gradually accumulates on this horizontal face, so as to make a pile with a triangular section, the base of which covers the face of the prism. After a short while the pyrites falls over on each side of the prism in two thin sheets, which, in descending, meet with two other prisms below so placed as to intercept it and cause it to accumulate again, and afterwards to fall over in four sheets, and so on. By successive descents over as many as twenty prisms the pyrites is brought thoroughly in contact with the heat and air of the furnace, and by the time it reaches the bottom there is not more than four or five per cent. of sulphur left in it. By openings, closed by movable stoppers in the side of the furnace, the process of oxidation of the pyrites can be seen, and the influx of air can be regulated.

UTILIZING THE RESIDUE FROM THE PYRITES FURNACE.

This residue, notwithstanding the little sulphur remaining in it, is used in the high furnace, mixed with ores for the production of iron. Mr. Bell, near Newcastle, and Perret in his operations, has shown that, by the addition of a little common salt in the desulphurizing process, iron of a good quality can be made from this material. When this waste product from the manufacture of sulphuric acid becomes useful in a remunerative industry, another great impulse is given to the production of this acid from pyrites.

COMBUSTION OF PYRITES COMPARED WITH THAT OF SULPHUR.

It is found, in making sulphuric acid from pyrites, that larger chambers are required, and a larger quantity of nitre in proportion to the sulphur burnt, than when sulphur is used. This arises from the higher temperature of the vapor from the pyrites, and from the greater quantity of inert gas that circulates through the apparatus. Too much attention cannot be given to diminishing the temperature of the gases, but in most works it is neglected; some, however, pass the gases through a kind of tubular boiler of lead surrounded by water, and thus cool down the vapors before they enter the chamber. Another precaution to be observed is, not to let the lump pyrites exceed the size of an egg, and to free it from fine matter that would clog the openings. There is very convenient machinery devised that will answer this purpose very well.

The little loss by the augmentation of inert gas in the chamber where pyrites is used may be diminished by determining, by frequent analyses, the proportion of sulphurous acid introduced into the chamber, a method now slowly growing into use; tests being made with a solution, *titrée*, of iodine, colored by starch. The gas is drawn from the chamber by means of an aspirator, and the water flowing from the aspirator is measured in a graduated vessel, which gives the bulk of the inert gases mixed with the sulphurous acid. This last is absorbed and calculated from the iodine solution through which the gases are made to pass. The mean of these analyses gives nine per cent. of sulphurous acid, which, according to the composition of the air and pyrites, ought to be mixed with 79 of nitrogen and 8½ of oxygen. This method of testing is well adapted to chambers where nitric acid is used or having nitrification furnaces constructed at the base of the chambers; but this testing can be used for all chambers at the exit, where the gases commonly contain six per cent. of oxygen. It would be well to diminish this quantity, taking care, however, that the oxygen does not disappear entirely, as this is a guarantee against the loss of binoxide of nitrogen, which is not absorbable by the cascade of sulphuric acid of Gay Lussac, when the proprietors of works are prudent enough to use his method of preventing loss of nitrous vapors.

Proper manipulation of the pyrites method depends on the nature of the combustion of the pyrites and the regulation of the draught of air. When the furnaces are well constructed with this in view, there can be obtained 126 parts of sulphuric acid for 100 parts of pyrites of 45 per cent. of sulphur, thereby utilizing as much as 42 per cent. of the sulphur. There is no greater drawback to this method of making sulphuric acid than the admission of too much air.

OXIDATION OF SULPHIUROUS ACID BY NITROUS ACID VAPORS.

The compounds of nitrogen and oxygen are used as agents to complete the oxidation of the sulphurous acid by a reaction familiar to chemists. The introduction of the nitrous vapors into the lead chambers is carried on in several ways in Kuhlmann's large works at Lille, and in other factories in France a small stream of nitric acid is allowed to flow into the nitrification chamber, the size of the stream being regulated so as to furnish the proper proportion where it reacts on the sulphurous acid at a comparatively low temperature. It is a good process, and may be regarded as a more natural process than any other in supplying the nitrous vapors. The acid is allowed to enter into the first chamber in a small stream; it is made to strike on glass gutters, or a stone-ware vessel, in such a manner that the liquid acid is divided into spray. As this falls into the chamber, and comes in contact with the sulphurous acid, it only furnishes the useful nitrous products, there being no formation of protoxide of nitrogen, or nitrogen, as sometimes happens from a rapid action on the nitre pans, as when they are carelessly heated red-hot. The operation is very regular, and the economy in nitric acid more than compensates for the expense of first forming the nitric acid. .

The more common process is by the action of sulphuric acid on nitrate of soda, and passing the vapors thus produced into the lead chambers. The method usually employed in England is the best for carrying out this decomposition, it being carried on in one instead of several vessels, and placing the vessel very near the entrance into the lead chambers. The quantity of nitrate of soda used by the several manufacturers for every 100 parts of sulphur, as stated by C. R. Wright, is:

For pyrites containing 45 to 50 per cent. sulphur.....	8.5 per cent.
For pyrites containing 30 to 50 per cent. sulphur.....	12.0 per cent.
For pyrites containing 35 average per cent. sulphur.....	12.5 per cent.
For pure sulphur.....	10.0 per cent.

EFFORTS TO PRODUCE SULPHURIC ACID WITHOUT THE AGENCY OF NITRIC ACID OR NITROUS VAPOR.

Several methods have been proposed, but no one of them has proved successful. Tennant Dunlap has approximated to success by a method which is in use, whereby having once produced the requisite supply of nitrous vapors no more are required except to make up the unavoidable loss. As this process is not familiar to most of our manufacturers, it will here be described, although it has been in successful operation for several years in the gigantic chemical works of C. Tennant & Co.

Instead of treating nitrate of soda with sulphuric acid, and employing the nitric acid thus obtained, a mixture of nitrate of soda and of chloride of sodium is decomposed, which yields, together with sulphate of soda, chlorine gas and nitrous acid. These gases are separated by passing them through concentrated sulphuric acid of not less than 1.75 sp. gr.,

when the nitrous acid is absorbed, the chlorine being utilized for the production of chloride of lime. The sulphuric solution of nitrous acid is allowed to flow into the chambers, where, by appropriate apparatus, it is brought into contact with water, which disengages the nitrous acid. At the works of Messrs. C. Tennant & Co., where this process is in use, they employ Gay Lussac's process for absorbing the nitrous acid from the escaped gases of the chambers, and M. Dunlap's process is used to such an extent as is found needful to provide for the waste of nitrous acid which occurs, notwithstanding the use of Gay Lussac's process. It will thus be seen that the immense quantity of sulphuric acid made by the Messrs. Tennant & Co. is formed without any nitrate of soda used specially for obtaining nitrous gas to be applied to the oxidation of sulphurous acid.

CONDENSATION OF NITROUS VAPORS BY GAY LUSSAC'S PROCESS.

The condensation of the excess of nitrous vapors that escape at the exit of the furnace in sulphuric acid works, by Gay Lussac's process, is very generally employed in France, but to a very small extent in England, where eight to ten parts of nitrate of soda are employed to every 100 parts of sulphur burnt. In all well-directed establishments this apparatus should be used to save the excess of nitrous vapors, and, while its use requires skill and care, it will reduce the quantity of nitrate required to less than two-thirds, and the saving will very much more than pay for the increase of expense and attention. This method has been long known, and is fully described in works on industrial chemistry, so that no detail of it need be given in this report.

PURIFICATION OF SULPHURIC ACID FROM ARSENIC.

The acid is sometimes boiled with a little common salt, and the arsenic goes off as tetrchloride of arsenic. But probably the most efficient and practical method is that adopted by Kuhlmann in his large acid chambers. The sulphurous acid from the combustion of the pyrites passes into a small chamber of 1,500 cubic feet capacity, that communicates with the furnace by a large leaden pipe forty or fifty feet long, sustained on its inside by iron bands covered with lead. In this way the sulphurous acid is cooled before it reaches the acid chambers, and several condensable products are deposited, among them the arsenious acid.

It is also purified by means of sulphide of barium, at Chessy, as it comes from the lead chamber, or by sulphuretted hydrogen; this last is successfully used at Freiberg in the following way: the apparatus used for making the sulphuretted hydrogen is composed of two large leaden vessels, placed side by side, and communicating with each other at the bottom. One of the vessels is filled with sulphide of iron and the other with diluted sulphuric acid. The gas as it is produced enters a long column full of coke, while the acid from the chamber is run through the coke by a kind of receptacle that alternately fills and empties itself,

thn's giving an intermitting flow. As the acid has time to spread over the coke, the sulphydrie acid and the arsenious acid react on each other. The flow of gas is regulated according to the quantity of arsenic present. The acid thus acted on falls into a leaden receptacle, is allowed to settle before it is concentrated in the lead pans, and, finally, in the platinum still.

The separation and purification from nitrous acid, when the sulphuric acid contains it, can be effected by adding either a little sulphate of ammonia or alcohol in the lead pans used in the first concentration.

CONCENTRATION OF SULPHURIC ACID.

It is well known that the acid as it comes from the lead chambers is first concentrated in lead pans. Little or no improvement has been made in this part of the concentration. In these pans the acid can only be brought to a degree of concentration eqnal to 1.70 sp. gr. Further concentration is carried on in glass or in platinum vessels.

The high price of platinum, and its monopoly by the Russian government, from which it gets into the hands of a few manufacturers, has driven many of the makers of sulphuric acid to return to the use of glass which they had once abandoned. In addition to this there has been considerable improvement in the manufacture of large lead-glass vessels, so that now about four-fifths of the acid made in England and Belgium is concentrated in glass, of which the original price and breakage, &c., does not exceed half of the annual interest of the cost of platinum stills. The vessels are very large, and are heated in open fire, or in iron pots, with a thin layer of sand between them and the sides of the pots. The vessels are kept constantly at work. The acid is drawn off by a siphon, and the vessels are immediately refilled with hot acid. The temperature of the room must be kept very warm, and a proper provision should be made for carrying off the vapors. The heat and the presence of the vapors of acid are very injurious to the workmen, and they suffer more or less from them. In this way, in South Lancaster alone, 700 tons of sulphuric acid of 1.85 sp. gr. are manufactured weekly.

In France platinum stills are almost altogether used, and the manufacturers of these vessels have exercised their ingenuity to diminish their cost, and none of them have succeeded so well in this direction as Messrs. Johnson & Matthey, of Hatton Garden, London. In 1862, in London, they exposed a still capable of concentrating from two to four tons of acid in twenty-four hours, for not much more than twenty-five per cent. of the former prices. The apparatus cost \$2,300. In 1867, when I visited their establishment, they were actively engaged in the manufacture of platinum stills, making some with the neck of the still directed upwards, to prevent the violent boiling of the acid from throwing over portions of concentrated acid. The form of one of their stills, its dimensions, and the shape of the upturned neck, are shown upon Plate VII, Fig. 1. The platinum stills exhibited coming from the establishments of Desmontes,

Chapins, and Quennessen, in Paris; Herasus, of Hanau; and Johnson and Matthey, of London, were most beautifully executed. In soldering all of these makers use gold, except the last-mentioned firm, who burn the sheets of the metal together at the seams and joints with the oxy-hydrogen blowpipe, and for large vessels of platinum the last-mentioned manufacturers turn out work more to my satisfaction than any of the others.

It is not usually understood that while platinum is not virtually acted on by sulphuric acid it does experience a little and gradual loss of substance by the action of the acid, and this especially when it contains nitrous acid, but this last can be prevented by adding a little sulphate of ammonia prior to distilling. Even when this precaution is taken there is still a loss, less in new and more in old vessels, commencing with a loss of one gram and gradually increasing to two grams for every ton of acid concentrated. When the platinum contains iridium the loss is diminished 50 per cent., but the Paris manufacturers, I believe are the only ones who have used iridium in their platinum, and they do not do it except by express order, for platinum that contains it is more difficult to work.

With this I will terminate the brief review of the present condition of the manufacture of sulphuric acid in the world, as brought out by the Exposition of 1867, and by the examination of old and well established factories.

A complete set of working drawings for model sulphuric acid works is appended. Full explanations and details will be found on the plates and in the explanatory pages accompanying them at the end of the report.

CHAPTER II.

SODA AND SALTS OF SODA.

PRINCIPAL SOURCES OF SODA AND ITS SALTS—WIDE AND GENERAL DISTRIBUTION OF SODA AND ITS COMPOUNDS—THE PROCESS OF LEBLANC; ITS IMPORTANCE AND PERFECTION—SULPHATE OF SODA; ITS MANUFACTURE AND USES—SULPHATE OF SODA FROM THE MOTHER WATER OF SALINES—OTHER SOURCES OF SODA—THE MANUFACTURE OF SODA FROM SALT—SULPHATE OF SODA FROM SALT—MAKING BLACK-ASH—EXTRACTION OF THE CAUSTIC SODA—THEORY OF THE PROCESS—MANUFACTURE OF SODA AND CARBONATE OF SODA FROM CRYOLITE—CRYOLITE AND ITS SOURCE—DECOMPOSITION OF CRYOLITE—PURE SODA MANUFACTURED FROM THE METAL.—BISULPHITE OF SODA—HYPOSULPHITE OF SODA.

PRINCIPAL SOURCES OF SODA AND ITS SALTS.

It is unnecessary in this place to detail facts upon the manufacture of soda and its salts familiar to chemists and to be found in all works on technical chemistry. Mention will only be made of the more striking results developed during the past few years, especially as exemplified by the Exposition. We purpose to notice the most important of the compounds of soda used in the industrial arts, and whatever may be thought necessary to detail in relation to their manufacture, statistics, &c. There is no substance so well known or so universally in the hands of all as that of soda, either in the form of sal soda and bicarbonate of soda, or in combination forming soap and glass. As the production of sulphuric acid from pyrites was caused by restrictions placed around the introduction of sulphur into various countries, so the present process of manufacturing soda was developed by a similar restriction, but from a different cause. The war in which France was involved in the latter part of the last century created a great scarcity of soda in France. It was imported principally from Spain, where it was made from sea-weed, and by this scarcity attention was drawn to the process of Leblanc, then recently discovered. The first city in France in which the manufacture was established, viz., Marseilles, is still largely engaged in its production, as well as in the manufacture of its natural offspring, soap.

PROCESS OF LEBLANC—SODA FROM SALT.

It is certainly in place here to refer to the origin and history of the great discovery by Leblanc, and in doing this I will use the words of Hofmann and of Ward in writing on this subject.

The ever memorable discovery, by the illustrious Leblanc, of the process now everywhere in use for manufacturing carbonate of soda from

common salt, stands distinguished in the annals of industry, not only as by far the most important of all chemico-industrial inventions, but also (a signal fact) of having been created perfect. All the other great chemical industries have been slowly worked out by the toil of successive inventors, but Leblanc's process, the greatest of them all, remains to this day what it was when he first gave it to the world, the best and simplest method of effecting the most valuable of all known transformations. Though eighty-six years have elapsed since this splendid discovery was made, and innumerable researches have been undertaken with a view to its improvement, the original indications of Leblanc are all but universally followed, with merely a few comparatively unimportant modifications.

It might have been expected that a process which, at its first introduction, was examined by a government commission of thoroughly practical men, and which, after having been submitted to comparative experiments, made with the greatest care, was recommended in an elaborate official report, would have been almost immediately adopted throughout Europe, with proportionate advantage to its discoverer. Such reasonable hopes, if entertained by Leblanc, were destined to cruel disappointment. Leblanc himself never reaped the reward of his admirable discovery. This man, who was certainly one of the great benefactors of his race, and to whom, long since, France and England should have joined to raise a statue, lived in poverty and died in despair. The creator of incalculable wealth for his species, he wanted bread himself; and, after endowing man with cheap soda—that is, with the inestimable blessings of cheap glass and soap, cheap light and cleanliness, and a hundred collateral advantages—he was suffered, to the shame of Europe, to end his days in a hospital. There he lingered, a wreck in fortune, health, and hope, till reason herself gave way at last, and he perished madly by his own hand. It is to be hoped that with the advance of civilization these terrible tragedies, so frequent in past ages, will become more and more rare, till the future historians of progress shall be spared the pain and shame of recording any more such outrages on justice—such ghastly martyrdoms of genius.

SULPHATE OF SODA.

More than six-tenths of the sulphuric acid manufactured is used in the manufacture of the soda salts. The old method of making sulphate of soda by acting on common salt with sulphuric acid is universally adopted. A fact worthy of note in regard to this salt is, that the French sulphate is much purer than that made in England, which must be owing to the more careful manipulation by the French manufacturers. The French sulphate is of remarkable whiteness, as I have seen in the factory of Kuhlmann at Lille; the sulphate manufactured there is largely used in Belgium and France for making the finest plate glass. A process of making the sulphate was at one time employed near Liverpool by mixing iron pyrites and salt; the result of the reaction being volatile ses-

quichloride of iron and sulphate of soda, which last was separated by the aid of hot water.

The principal use of sulphate of soda is to manufacture the carbonate by the process of Leblane, which, although over eighty years old, has never been supplanted by any other.

SULPHATE OF SODA FROM THE MOTHER WATER OF SALINES.

In France and Germany the mother waters of the salines are worked to extract the salts that they contain, and by the process of Balard. By using carefully regulated temperatures, these salts are crystallized out. The sulphate of soda may be obtained in this manner, but as this salt made by the direct action of sulphuric acid on common salt is obtained more cheaply, the process is not much resorted to. The principal object of treating these mother waters is to extract the potash salts.

SODA FROM CRYOLITE AND FROM SODIUM.

Soda is now largely obtained from cryolite, an interesting mineral which occurs in abundance in Greenland, and it is also prepared to a limited extent from the metal. These two sources will be considered at length after some details upon the manufacture of soda by the process of Leblane have been given.

MANUFACTURE OF SODA FROM SALT.

This resolves itself essentially into four operations :

1. Formation of sulphate of soda by decomposing common salt.
2. Heating the sulphate of soda mixed with lime and charcoal in a furnace to form what is called black-ball.
3. Lixiviation of the black-ball with water to extract the alkaline products.
4. To obtain caustic soda and carbonate of soda by proper evaporation and concentration of the liquor.

THE FORMATION OF SULPHATE OF SODA.

There are two methods by which sulphate of soda is produced—namely, in the moist way in leaden vessels, and by the dry way in furnaces. The former is employed to a very large extent, and must always be used where a pure white sulphate of soda is required. M. Kuhlmann, at Lille, manufactures a large quantity of this description of sulphate which is afterwards heated in hot chambers and all its water of crystallization driven out, forming a pulverulent mass as white as the driven snow, and used largely by the glass makers, which could not be done if the decomposition of the salt was conducted in iron vessels. The more common form in England of decomposing the salt in a furnace of a peculiar construction is fast coming into use everywhere where the sulphate only is used for the subsequent operation of transforming it

into carbonate. The process most generally adopted will be described particularly, as it affords a very complete condensation of the hydrochloric acid formed, so much so that the use of this process in Belgium is compelled by law. An account of the furnace as constructed and used in the works of Tennant & Co. has been given by Professor Hofmann, and I use his own words in describing it.

As this apparatus is now generally arranged, it consists of a muffle constructed of cast iron, and a second muffle constructed of brick work. The lower part of the iron muffle represents the segment of a hollow sphere, made of thick cast iron, nine feet in diameter in its widest part, and one foot and nine inches in depth. This is placed on a seating of brick work, and is surmounted with a cover of cast iron, also the segment of a hollow sphere, about one foot deep in the center. This cover has two doors, through one of which the salt is introduced, while through the other the mixture can be passed into the brick muffle. A fireplace is arranged beside the iron muffle, and a flame is passed firstly over the iron cover and subsequently under the iron pan. The requisite heat is thus given to the contents of the muffle by transmission, and the gas is evolved at a comparatively low temperature unmixed with air. The brick muffle is adjacent to the iron one, both being seated on the same pile of brick work, and having flues which communicate with each other. The brick muffle consists of a chamber about thirty feet long and nine feet wide, having a floor constructed of bricks, which forms the covering of a number of flues; the upper part of this muffle is formed by a thin arch of brick work, which is again surmounted by a brick arch, a flue being thus formed between the two arches. A fireplace is arranged at one end of the brick muffle, the flame of which is first caused to traverse the flue between the two arches of the muffle and then to return through the flues under the brick floor. Heat is thus applied to the contents of the muffle by transmission through the brick work of its arch and floor.

In using this apparatus, half a ton of salt is thrown into the heated iron muffle, and the requisite quantity of sulphuric acid, of about 1.7, is run upon the salt. The mixture is assisted by the use of the iron rake, and a strong effervescence of hydrochloric acid ensues. The mixture generally thickens, and at the expiration of about one hour and a half, (when about two-thirds of the hydrochloric acid has been driven off,) it becomes pasty and ready to be transferred to the brick muffle. This is effected by pushing the pasty mixture through the channel of communication between the two muffles. To complete the expulsion of the hydrochloric acid, it is needful to maintain a red-heat in the brick muffle. A provision is made for closing the communication between the two muffles, so as to have the power of keeping separate the gases proceeding from each, as the gas from the brick muffle will furnish a more concentrated acid, by condensation.

The acid gas that escapes from this furnace is condensed by one of

the methods described under the head of hydrochloric acid. Furnaces of the above description have been in use in the works of Tennant, at Glasgow, for twenty years, decomposing 500 tons of salt weekly, and with the most perfect success, and no annoyance to the neighborhood by acid vapors.

MAKING BLACK-ASH.

The second process consists in mixing sulphate of soda with lime and heating it in a furnace. The proportion of these ingredients is not the same in all manufactories; they vary nearly as follows at different places: Sulphate of soda, 100 parts; carbonate of lime, from 121 to 90 parts; coal, from 71 to 35 parts.

These differences arise from the difference in the purity of the materials, some using anthracite coal giving 80 per cent. of solid carbon, others using coal giving only 60 per cent. of carbon, and 10 to 18 per cent. of ash.

Kuhlmann, who uses a coal leaving about four or five per cent. of ash, employs sulphate of soda and carbonate of lime, 100 parts of each, and 37.7 parts of coal.

The three ingredients above mentioned are placed in furnaces of different descriptions, fully described in works on technical chemistry; the materials are not pulverized, the coal and lime being both thrown in in lumps, as the method of manipulation renders the finished material easier of lixiviation in the next operation.

The only furnace that may be considered as an innovation of the older one, is the English revolving furnace. It has been employed since 1861, and although there was a disposition at first to condemn it, it has gradually grown into favor and will doubtless soon find its way into France and other continental countries. Mr. Stevenson describes one of those first erected as follows: It consists of a horizontal cast-iron cylinder, eleven feet long, and seven and a half in diameter, lined with nine-inch brick work. Two circular openings, about two feet in diameter, in the ends, allow the flame from the furnace to pass through the cylinder and over its contents. The cylinder rests on four rollers, one pair of which is turned by machinery, so as to cause the cylinder to revolve. The charge is introduced from a hopper above, through a door in the middle of the cylinder, and the charge runs out at the same door when the decomposition is completed, the cylinder being stopped for this purpose, with the door downwards. No tools being required to turn over the materials, the furnace can be kept closed, its brick lining lasts a long time, and the saving of manual labor is considerable. A revolving furnace of the dimensions given above decomposes 1,400 weight of sulphate of soda every ten hours, at the cost of 43 cents per ton, including wheeling and charging the materials.

This furnace is heated by the products of combustion passing through it from end to end, there being a fireplace at one end of the apparatus and a chimney at the other. At the present time the dimensions of these

are made even larger; some of them are seventeen feet long by twelve feet in diameter, into which the carbonate of lime is first introduced in large fragments and the cylinder put in motion slowly, then the sulphate of soda and coal are added, and the motion is accelerated. In such a furnace three tons of matter can be treated at one time. A very active combustion is kept up in the furnace, so that there may be heated flame in the whole length of the cylinder; the excess of heat is not lost, but is used for the evaporating pans, &c. "Black-ash" is the name given to the material as it comes from the furnace, and it is usually made up into balls while still hot. A good deal of this ash is sold at once to the soap makers, but most of it is lixiviated, and from the solution soda-ash, crystallized soda, and caustic soda are made. As there is no improvement in the beautiful method long employed in England and elsewhere for lixiviation, and which is said to be due to Mr. James Shanks, of St. Helens, we will not give any details on this subject, but refer those desiring further information to the excellent description of the method to be found in various books. The grand result aimed at and accomplished is the complete washing out of all soda from the black-ash with the least quantity of water.

The black-ash compound consists essentially of carbonate of soda and sulphide of calcium, but then there are various other substances in small quantities arising from impurities in the ingredients or from imperfect decomposition. When treated with water this compound yields considerable caustic soda; this, however, is not supposed to be in the ash, but to be produced by the action of water in the presence of the oxysulphide of lime that is converted into carbonate of lime and sulphide of calcium.

CAUSTIC SODA FROM BLACK-ASH.

It has been stated that some of the carbonate of soda formed in the furnace operation is converted into caustic soda by the treatment of the ash with water. Formerly it was the habit either to dry the mixed soda mass and send it to market as soda ash, or to convert it into carbonate of soda and crystallize it as soda crystals, but for several years much of this soda has been sold as caustic soda, especially since the adoption of Gossage's process of separating the caustic soda simply by a judicious process of evaporation. Although this method has been employed for some time on an extensive scale, it is thought advisable to give a condensed description of it from the Exposition report for 1862, particularly as time has approved its value. The crude liquors obtained by exhausting black-ash are evaporated to a considerable degree of concentration, so as to separate a greater part of the carbonate, sulphate, and chloride of sodium. When the liquor has been brought to a specific gravity of 1.5 nearly all the foreign salts are deposited, and there remains in solution caustic soda, a peculiar red compound of sulphide of iron, (which has procured for these solutions the name of red liquors,) together with small quantities of carbonate, sulphate, chloride, ferrocyanide, and some-

times sulphocyanide of sodium. Chloride of lime or nitrate of soda is now added to oxidize the sulphide, and after concentration to 1.6 specific gravity, at which time more salt is deposited and raked off, it is run into settling vessels and again placed in the evaporators and concentrated and kept for some time in a state of igneous fusion when further deposits take place, and when it is concentrated so as to contain about sixty per cent. of anhydrous soda, it is run into sheet-iron vessels with the joints made tight by gypsum. It is closed up firmly and perfectly and then delivered to commerce, and is used by the paper-maker, soap-maker and others.

THEORY OF THE MANUFACTURE OF SODA BY LEBLANC'S PROCESS.

Notwithstanding more than eighty years have elapsed since the manufacture of soda by this process, it is only since 1862 that anything like a clear solution of the problem has been propagated—one which seems to have very nearly cleared up all difficulties connected with its explanation.

In the furnace the first change takes place, at a comparatively moderate temperature, when the sulphate of soda is converted into sulphide of sodium. At a higher temperature a reaction takes place between the sulphide of sodium and carbonate of lime, when carbonate of soda and sulphide of calcium are formed, with the escape of carbonic acid; which sulphide of calcium was formerly thought to be soluble, but the insolubility of it when made by fusion is now clearly established. This reaction can be accomplished with an atom each of sulphate of soda and carbonate of lime, with the necessary amount of coal for the deoxidation; but most commonly an excess of lime is added to furnish a larger surface to the fused sulphide of sodium. In order to accomplish more readily the decomposition of the sulphide, an excess of coal is added to increase the temperature of the mass, and it also contributes at the end of the decomposition to transform the excess of carbonate of lime into caustic lime, and when this takes place (and at no other time) carbonic oxide is given off, the escape of which gas is an indication that the operation is at an end; the porosity of the pasty mass, so useful in the subsequent operation, is brought about by the escape of this last mentioned gas.

This mass which constitutes the black-ash undergoes new decompositions when brought in contact with the water required to extract the carbonate of soda. In the first action of the water it is found to contain besides the carbonate of soda only traces of caustic soda and sulphide of sodium; but as the action of the water is continued and time is given for the caustic lime to become hydrated, the quantities of the caustic soda and sulphide of sodium increase with a proportional diminution of the carbonate of soda.

The above may now be considered as the true nature of the changes that go on in the making of carbonate of soda from sulphate of soda.

If the water used in treating the black ash in the vats generally adopted for some time be evaporated and the dry mass treated in the

soda furnace so as to oxidize the sulphide of sodium, we obtain the ordinary soda-ash, composed of carbonate of soda, caustic soda, and sulphate of soda; this is productive of some loss, so that another method has been adopted for many years by which the soda value of the ash is increased. In treating the black-ash with water, the first portion of the water is strongly saturated with soda-salt and caustic soda, containing hardly a trace of sulphide; this portion is evaporated separately and dried, furnishing a salt almost pure; the last portion of water with which black-ash is treated is a dilute solution of the salts with considerable sulphide of sodium. This solution is treated with carbonic acid, which combines with the caustic soda and decomposes the sulphide. This last solution is now evaporated to dryness and furnishes quite a pure carbonate of soda. A still further improvement by Mr. Gossage has been made within the last ten years in the treatment of the solutions for the purpose of furnishing commercial caustic soda, an account of which has been already detailed.

MANUFACTURE OF SODA AND CARBONATE OF SODA FROM CRYOLITE.

Many and vain have been the attempts to supersede the process of Leblanc for the production of soda, and vast amounts of ingenuity and capital have been expended without success. But this statement does not apply to the production of soda, to a limited extent, out of a curious mineral found in Greenland called cryolite. This mineral was exhibited in abundance at the Exposition, and as there is an important manufacture of soda from it established at Natrona, Pennsylvania, the details of the method employed will be briefly described. These details have been kindly furnished to me by J. A. Hagemann, the chemist of the Danish Cryolite Mining Company, who directs at this time the manufacture of soda from cryolite by the Pennsylvania Salt Manufacturing Company. We may look for the best information on the subject to the above named company's works, which are imitations on a large scale of the factory built by Julins Thomsen, of Copenhagen, in 1856. Some information has also been obtained from an essay by Sam. F. Simes.

CRYOLITE AND ITS SOURCE.

Before proceeding to a description of the process of manufacture it is well to give some short account of this mineral and its present commercial movement.

The mineral cryolite, or "ice-stone," has been known as a mineralogical rarity for many years, as far back as the latter part of the last century; thirty years ago it was worth fully a dollar an ounce, and it was considered only as a rare and curious mineral, of no value in the arts. Up to 1850 no attempt had been made to put it to any practical use, although

it was known to exist in Greenland in large quantities and to contain a large amount of soda, for its composition is—

3 Sodium.....	69
2 Aluminium	27.26
6 Fluorine	114
	<hr/>
	210.26

It has a specific gravity of 2.95 with a hardness of 2.05. Much of it is found colorless and pure. The associate minerals are galena, blende, spathic iron ore, iron pyrites, and copper pyrites.

With the exception of some few scattered specimens that occur at Miask, in the Ural mountains, it is found exclusively in Greenland, and in immense quantity. It is procured from the mines of Ivigtout on the west shore of South Greenland, on Arsuk Fiord, between Julian's Hope and Frederick's, latitude 61° north, longitude 48° west. The main deposit here forms a mass six hundred feet in length and two hundred feet in width, and descending to an unknown depth. It lies at the base of granite hills, that rise a little distance from the edge of the Fiord, the shores of which are very bold and are almost fathomless a few feet from the shore.

The Danish government is the owner of this mine, and in 1864 Christian IX granted the exclusive right of mining cryolite to the "Cryolite Mining Company of Handelselhabet," a company organized in Copenhagen. This contract was made by a Danish company in consequence of the results of the labors of a young Danish chemist, Julius Thomsen, in 1850, who discovered a cheap and easy method of rendering cryolite available in technical chemistry for the manufacture of soda and alum, and his process is carried on in Europe and this country on such a scale as to consume annually twelve to fifteen thousand tons of cryolite.

PROCESS OF DECOMPOSING CRYOLITE.

Thomsen's process of decomposing cryolite is simply by lime, either in the wet or dry way. The decomposition may be represented by the following formula:

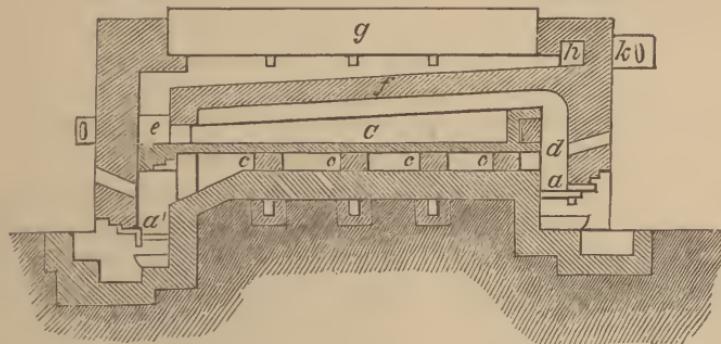
$2(\text{Al}_2\text{Fl}_3 + 3\text{NaFl} + 6\text{CaO}) = 3\text{NaO} + 2\text{Al}_2\text{O}_3 + 3\text{NaO} + 12\text{FlCa}$.
Another method is to calcine finely powdered cryolite and mix it with six equivalents of lime; the product will be "caustic soda, aluminate of soda, and fluoride of calcium." Another is to boil cryolite with the same proportion of lime in the form of milk of lime, and a similar decomposition takes place. The soda and aluminate are soluble in water; the latter is subsequently decomposed by carbonic acid. Both the wet and dry process will now be described.

THE DRY PROCESS.—The cryolite is dried in a furnace, and by a crusher is reduced to small fragments, which are ground in a burrstone mill to a fine powder, and uniformity in the powder is insured by passing it through a bolter of fine wire gauze. The powder is then mixed with slacked lime, or with pulverized chalk, in proportion to its purity,

so that for each equivalent of pure cryolite there shall be a little more than six equivalents of lime. This mixture is effected on chaser mills, such as are used for crushing linseed and other oily grains. This mixture is now calcined, and here arises the great difficulty of the process, for the soda or carbonate of soda and the fluoride of calcium fuse at a low temperature, and if allowed to fuse would almost entirely prevent the subsequent lixiviation with water. Care must therefore be taken to prevent the temperature from rising high enough to fuse the mass, while at the same time the mass must be heated sufficiently to effect the decomposition.

When the factory at Copenhagen was erected in 1856, this decomposition was effected in iron retorts similar to gas retorts and set in the same way, and the carbonic acid so liberated (when chalk was used) was conducted to the vats to decompose the aluminate of soda from a previous operation. But this process entailed costly repairs and much expensive handling. Thomsen then constructed a furnace which is now successfully used in all the cryolite factories.

Fig. 1.



Furnace for decomposing Cryolite.

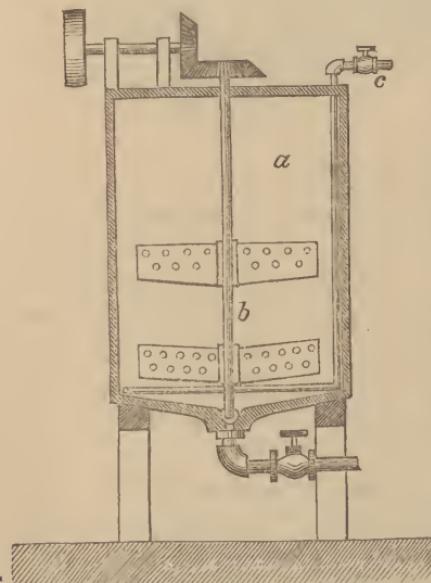
Fig. 1 is a sketch of this furnace one hundredth of its size. *a a'* are two fire-places. The flame from *a* passes underneath the hearth *C*, which is formed of large slabs of fire-clay two feet square, and supported on square pillars *c c c*. At *d* the flame from *a* meets the flame from *a'* and both pass over the hearth, when, arriving at *e*, they rise up and pass over the arch *f*, and thereby give off the last portions of heat to the evaporating-pan *g*, and, finally, at *h*, they pass into the flue of the chimney, having a damper, *k*, to regulate the heat.

The mixture is spread on the hearth about three inches thick, and is not disturbed for about one hour, at which time it is turned over with a rake and again left for about three-quarters of an hour, after which it is drawn out and fresh material is introduced, each charge being about 1,000 pounds. The decomposition should be complete in the portion withdrawn, and it forms a granular, loose mass of an ash color. After the mass has thoroughly cooled it is lixiviated in an ordinary tank, and

the dissolved soda and aluminate of soda is drawn off, and the residue is properly washed. The solution will, on an average, mark 26° to 28° Beaumé.

The lye, being a strong solution of soda, carbonate of soda, and aluminate of soda, is treated with carbonic acid in order to produce carbonate of soda and alumina. The carbonic acid is produced by the combustion of coke, and the products of combustion are drawn off by means of a fan, and passed through stacks filled with coke, down which water is made to trickle; and in this way the carbonic acid is washed and purified. The purified gas is passed from these stacks into a large horizontal cylinder, from 40 to 50 feet long, through the middle of which a shaft with paddles rotates. The cylinder is about half filled with liquor, the paddles are put in motion, and the gas is let on through one end of the cylinder, the unabsorbed gases escaping at the other end. When the solution is saturated with carbonic acid it is run off into settling-boxes capable of holding one charge. In about from four to six hours the alumina will have separated from the liquor which is drawn off, and the deposited alumina is freed from the adhering soda by washing it with water and filtering upon proper filters. The clear solution first drawn off has a density of about 31° Beaumé, and the alumina is left in the form of a granular powder. In this way two valuable products are produced from the cryolite—carbonate of soda and alumina. The latter contains but a trace of soda, and is a valuable material for the manufacture of alum and sulphate of alumina.

Fig. 2.



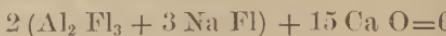
Apparatus used for the decomposition of $\text{Na}_2\text{O} + 2 \text{Al}_2\text{O}_3 + 3 \text{CaO} + 12 \text{Fl} = 2(\text{Al}_2\text{Fl}_3 + 3 \text{Na Fl}) + 15 \text{CaO}$

Cryolite in the wet way.

In either case the decomposition is effected as follows: Into a large vertical cylinder, *a*, Fig. 2, scale $\frac{1}{100}$, pro-

Considering the nature of the mineral and its impurities, sometimes amounting to 10 or 15 per cent., the carbonate of soda is remarkably pure, its only impurity being one or two per cent. of sulphate of soda, the sulphuric acid having been formed from the sulphides that are associated with the cryolite.

THE WET PROCESS.—If cryolite be boiled with six equivalents of lime, the decomposition which takes place is similar to what occurs in the dry process; but if two equivalents of cryolite be boiled with 15 equivalents of lime, the resulting product will be caustic soda, aluminate of lime, and fluoride of calcium.



vided with a perpendicular shaft having paddles, *b*, and a steam-pipe, *c*, ending close to the bottom in a perforated ring, is introduced milk of lime, made from about 15,000 pounds of good lime. The paddles are now put in motion, and the mass is agitated for a little time, and the liquid is then assayed and measured, so as to ascertain the exact amount of lime present. The cryolite is then added in fine powder in the proportion desired to accomplish a given result. Two equivalents of cryolite and 12 equivalents of lime will produce, as already stated, caustic soda and aluminate of soda. Fifteen equivalents of lime will furnish all the soda as caustic soda, with aluminate of lime. Fluoride of calcium is formed in both cases.

After two or three hours' boiling and agitation the decomposition is generally completed, (testing will indicate the liberation of all the soda,) and the contents of the agitator are discharged on a suitable filter. The clean liquor which will form on top of the sediment is drawn off, and the sediment is treated with water as long as the filtered liquid contains soda.

If the first proportion of lime has been used and aluminate of soda has been formed, the liquid is treated with carbonic acid, as in the dry process, and all the soda is converted into carbonate, and the alumina is deposited as an insoluble residue. If the latter proportion of lime is used, and all the soda be in the solution as caustic soda, all that it is necessary to do is to evaporate the liquid to dryness in pans or kettles. In this manner caustic soda containing 75 per cent. of NaO is manufactured on a very large scale at Natrona.

It is evident that the wet process is decidedly the simpler of the two, there being less handling and less costly apparatus; but the feeble strength of the lye produced (10°B) by this process, and consequently the large amount of water to be evaporated, is a great drawback to it. Where alumina is of but little value and caustic soda is much sought after, the wet process with 15 equivalents of lime may be most profitably employed. Where the contrary is the case, the dry process is to be preferred, producing a lye of 26° to 28°B, and requiring but little concentration in order to crystallize.

Besides working out all the details of this process, Julins Thomsen has devised volumetric processes of analysis adapted to different stages of the operation. Weber & Bro., of Copenhagen, not only furnished all the means necessary for conducting his experiments, but established a factory in Copenhagen and sent vessels to Greenland for the cryolite. Their factory has been the model on which others have been erected.

There are four establishments in Germany, consuming annually about 2,000 tons of cryolite; and in 1867 the one in this country was erected by the Pennsylvania Salt Manufacturing Company, having a capacity for working up about 6,000 tons of cryolite. This company, in 1867, imported 8,000 tons, and sent out to Greenland during the summer 19 vessels of an average capacity of 450 tons, of which two were lost in the ice. The approach to the coast is considered dangerous on account of

the fields of ice, which sometimes form a thick and impenetrable belt of 80 to 100 miles in width. Off the western coast of Greenland the wind scatters the ice, and a good navigator can penetrate the openings without delay. No loss of life has yet occurred in this trade, as the ice affords a refuge for a shipwrecked crew until removed by the Esquimaux or until they escape by their boats to the settlements. The mines are worked, from May to October, by about 150 men. In the salt works of Natrona, Pennsylvania, more than half a million of dollars have been invested, and employment has been given to 500 men. The alumina manufactured there in connection with the soda is supplied to the largest makers of alum in this country; but this will be referred to again under alumina. The various manufactures from cryolite have a market value of over \$1,500,000 in gold.

There has been no important improvement on Thomsen's processes, except it be one by G. A. Hagemann, on which a patent has just been obtained.

Beauxite (a mineral containing 80 per cent. of alumina) is sometimes mixed with the cryolite to increase the yield of alumina, and this process will be referred to under the part of the report relating to alumina.

Much space has here been devoted to this manufacture of cryolite soda, from the fact that cryolite and its products were conspicuous in the Exposition, and that the value of cryolite and its treatment as a soda-yielding substance, is but little understood and appreciated by technical chemists generally.

PURE SODA FROM SODIUM.

One of the most curious triumphs of modern chemistry is the production of *pure soda* from the metal sodium at a price cheaper than the same article can be made by any other process previously adopted. It was made and exhibited by the firm of Messrs. Johnson & Matthey, of London. The bars of sodium, as they are now made by several European chemists, after the method of Deville, are cut into fragments of about a cubic inch in size. One of these fragments is thrown into a silver dish, floating on a stream of cold water; a little distilled water is poured on the sodium, and the vessel is agitated by the hand, which prevents explosions. After the first lump is dissolved another lump is thrown into the silver capsule and treated in the same way; and so on successive lumps are added. After a deposit of soda forms at the bottom and on the sides of the vessel the tendency to explode diminishes, but it is important to keep the vessel agitated to prevent the burning sodium from being scattered. The solution is somewhat milky, and must be filtered and evaporated, and then fused in a silver capsule or crucible, until the moisture is driven off and the mass is transparent; it requires a dull-red heat for this purpose. It is removed from the crucible while hot, broken up, and put in well stopped bottles. The operation is a slow one, and is disagreeable from the odor of the vapors and the danger of explosion. A steady

workman can treat in this way one and a half pound of sodium, or, with two dishes, two pounds of sodium. Pure soda is thus made and sold for \$1 75 in gold per pound, including bottle and packing case, the metal sodium being sold by the same parties at \$1 30 per pound, including the tin canister and packing case.

OTHER COMPOUNDS OF SODA.

BISULPHITE OF SODA.

There is no improvement in the ordinary way of making this material, viz., by passing sulphurous acid, made in any way found cheapest and most convenient, into a solution of carbonate of soda. Its use is extending more and more every day, frequently under the name of leucogene, for bleaching wool; also for bleaching vegetable textile matters, as cotton, linen, hemp, jute, phormium, &c. It gives a silky white color to threads and tissues that cannot be obtained by hypochlorites. M. Chaudet, of Ronen, manufactures annually 140 tons of leucogene, representing 2,000 tons of white wool. In 1866 he first applied bisulphite of soda and indigo to the blueing of wools. The process is to add to the ordinary leucogene from three to five parts by weight of blue dye for every 100 parts of wool to be bleached. The bleaching and dyeing take place at the same time.

HYPOSULPHITE OF SODA.

The use of this substance, which commenced with the art of Daguerre, has since extended to a variety of uses. As an antichlor, it is introduced into paper pulp to decompose the last traces of bleaching powder, which, if allowed to remain, attacks the paper and renders it brittle and friable; in the manufacture of antimony vermillion by the action of this hyposulphite or the salts of antimony, especially the terchloride; in metallurgy, after treating silver ores so as to form the chloride of silver, this chloride is dissolved out by the hyposulphite of soda. So much of this salt is now used that one establishment alone in Lancashire makes three to four tons a week. This salt is made in two or three ways. Kopp's method is to form it by a double decomposition with carbonate of soda and hyposulphite of lime. This substance can be readily obtained by oxidizing the soda-waste and submitting it to the action of carbonate of soda and evaporating the resulting solution of hyposulphite of soda to the point of crystallization. It is also formed by first converting the sulphate of soda into the sulphide by heating with carbon, dissolving in water, and treating by a current of sulphurous acid until the reaction is acid, neutralizing with a little caustic soda and evaporating to crystallization. Sometimes stacks of coke are used to bring the sulphide of sodium and sulphurous acid in contact, the solution of sulphide trickling downwards and the sulphurous acid gas ascending.

CHAPTER III.

POTASH AND ITS COMPOUNDS.

PRINCIPAL SOURCES AND USES OF POTASH AND ITS COMPOUNDS—POTASH FROM FELDSPAR—METHOD OF DECOMPOSING SILICATES—EXTRACTION OF POTASH-SALTS FROM SEA-WATER BY BALARD'S PROCESS—MERLE'S IMPROVEMENT—POTASH-SALTS FROM THE ROCK-SALT MINES OF PRUSSIA—GEOLOGY OF THE STASSFURT DEPOSITS—LIST OF THE MINERAL SPECIES FOUND AT ANHALT AND AT STASSFURT—THEORY OF THE ORIGIN OF THE DEPOSITS—EXTRACTION OF THE POTASH-SALTS—SULPHATE OF POTASH—NITRATE OF POTASH—POTASH FROM ORGANIC SOURCES—EXTRACTION FROM WOOD ASHES—EXTRACTION FROM ASHES OF SEA-WEED—EXTRACTION FROM SUINT IN SHEEP'S WOOL—USE OF POTASH-SALTS IN AGRICULTURE.

PRINCIPAL SOURCES AND USES OF POTASH AND ITS COMPOUNDS.

In years gone by, potash was the cheapest of the alkalies used in the arts, but that time has passed, and this alkali is now the most expensive of all, and consequently soda and ammonia have taken its place to a great extent. It is still, however, essential for some purposes where soda cannot be used, as for example, in the preparation of pure crystal-glass, to which soda gives a greenish hue, as potash-nitre in the formation of gunpowder, and in the formation of chlorates and cyanides. In the last series of compounds, the cyanides, baryta may in the future take the place of potash to a considerable extent.

Potash is furnished to commerce from the mineral, vegetable, and animal kingdoms; it is procured from products both from the land and from the water. The method of obtaining potash from the incineration of terrestrial plants is so well known, and was for so long a time the only way of obtaining this alkali, that any notice of it further than a mere mention is unnecessary.

POTASH FROM FELDSPAR.

There have been many attempts to separate potash from feldspar, (in which it exists in considerable quantities,) so as to produce it, economically, in large quantities for commerce, but no one has come so near accomplishing this successfully as Mr. F. O. Ward, in 1861. At the Exposition in London there were specimens of potash manufactured according to his process. He called the process of decomposing the feldspar the *calefluoric attack*, and he describes it as follows: "The feldspar, or other alkaliferous silicate which it is proposed to treat, is ground to the fineness of ordinary Portland cement, and mixed with a due proportion of fluorspar or other fluoride, also in powder. With this mixture a certain quantity of chalk, or preferably of a mixture of chalk

and hydrated lime, is incorporated, the mixture thus prepared is ignited at a yellowish red heat till the ingredients become agglomerated; this effect is obtainable in a time which varies from one to several hours."

The reporter may be excused for remarking, that although Mr. Ward is entitled to full credit for successfully carrying out this process into manufacturing chemistry, the reporter pointed out this process of decomposing silicates to obtain the entire amount of their alkalies eight years before Mr. Ward practised the method. The process was proposed and used by the writer for analytical purposes, and reference is made to a memoir on determining alkalies in minerals, published in the American Journal of Science, March, 1853. The reader of this report may contrast the following, taken from that memoir, with Mr. Ward's description as previously given: "Pulverize the silicate to a sufficient degree of fineness, it is not required that the levigation be carried to any great extent; mix intimately a weighed portion of the mineral with one part of fluorspar and four parts of carbonate of lime, introduce it into a platinum crucible. The crucible may then be covered and introduced in any form of furnace where a bright red heat can be produced." Reference is here made to this early use of the process, because in the report upon the exhibition of 1862 it was stated that all attempts to decompose the silicates successfully, with lime and fluxes, had failed of success.

This process for manufacturing potash has not been attended with the practical success expected in 1862, various causes having conspired against it, some of which will be alluded to hereafter. Considering this want of success, the details concerning it need not be given. It is a process which is not familiar to most of the technical chemists in this country; in fact, strictly speaking, it has not been carried out on a manufacturing scale, the largest charges operated upon being 240 pounds, and the yield seven-eighths of the potash present.

POTASH SALTS FROM SEA-WATER—BALARD'S PROCESS.

This is another mineral source of potash salts, and it was first devised by Balard some sixteen or eighteen years ago, and has been carried on successfully for many years, but is now seriously interfered with by the supply from the new source of potash in the deposits of potash compounds called "sylvine" and "carnallite," found occurring in the rock-salt mines of Stassfurt.

By Balard's method the potash salts are obtained in treating the mother-liquor of sea-water salt works, which we may regard as essentially composed of chloride of potassium, sodium and magnesium, and sulphate of magnesia. The object had in view is to bring all the sulphuric acid into combination with the soda, and then to obtain, by separate crystallizations, the chloride of sodium, the chloride of potassium, and the chloride of magnesium; the last, being of but little practical value, is allowed to run to waste. The means used to accomplish the results are alto-

gether physical, namely, the abstraction of heat by natural or artificial means. It is based on Scheele's observation made a great number of years ago, that if a mixture of chloride of sodium and sulphate of magnesia in solution be reduced below freezing point, a double decomposition takes place, and crystals of hydrated sulphate of soda are formed, and chloride of magnesium remains in solution. The separation of the mixed chlorides is made by boiling and cooling the mother-water freed from the sulphate of soda. The original process of Balard was much improved by M. Merle, who employs an artificial cooling process. The following is a detailed description of his process, as communicated by him to the chemical reporters of the London Exposition in 1862:

The process may be shortly defined to consist in the further concentration of concentrated sea-water by exposure to a low temperature, artificially produced. The degree of concentration requisite to fit sea-water for treatment by this process is 1.24 sp. gr., (28° B.,) at which point of concentration sea-water deposits about four-fifths of the culinary salt contained in it.

This degree of concentration is obtained by the ordinary process of evaporation on the ground as practiced in the manufacture of common salt, of which the ample crop obtained repays this preliminary operation. The mother-liquor which remains is the raw material of the new process. It is stored in large covered tanks, and from this point forward it undergoes no further exposure to dilution by rain, or to absorption by the soil. It is withdrawn from the ordinary operations of the salt gardens, from which M. Merle borrows the one first step—concentration of 1.24 sp. gr., (28° B.) As, however, this degree of concentration is found to be a little beyond the density most favorable to the next stage of the operation, ten per cent. of pure water is added to the liquor in the tanks. Thus prepared, the concentrated sea-water is next passed through refrigerating vessels, which are constructed on Mr. Carr's principle, and which cool it to 18° C. This artificial refrigerator causes the desired double decomposition to take place between the sulphate of magnesia and chloride of sodium, sulphate of soda being deposited by the water as it passes through the machine, and chloride of magnesium being carried away in solution. The process is continuous. The water passes constantly in at one end of the apparatus and out at the other, and the deposited sulphate of soda is continuously withdrawn from the apparatus by a chain of buckets. This salt is speedily freed from mother-liquor by a centrifugal hydro-extractor, and is finally dried in a reverberatory furnace. The utility of the above-mentioned dilution of the tank liquors is now made manifest. If cooled down while at their original density (28° B.) they would let fall much hydrated chloride of sodium, along with the sulphate of soda, to the detriment of its purity and value. But in consequence of the dilution the culinary salt remains dissolved, together with potassic and magnesic chlorides, in the mother-liquor which flows away from the machine.

This mother-liquor has now to be treated for the recovery of the salts it holds dissolved. For the recovery of the culinary salts the mother-liquor is made to flow from the cooling machine directly into boilers like those used in refining rock salt. In these it is boiled down to 1.331 sp. gr., (36° B_o.) by which time it has deposited nearly the whole of its common salt in a fine powder, which, when dried in a centrifugal machine, equals for purity the best English refined salt. It only remains now to recover the chloride of potassium still dissolved in the hot liquor, which, for this purpose, is poured forth to cool in extensive shallow coolers formed of concrete. Here it soon deposits the whole of its potash as a double chloride of potassium and magnesium. This deposit (a kind of artificial carnallite) is collected, and the magnesic chloride is eliminated therefrom by adding to the mixed mass half its weight of fresh water. This dissolves the whole of the more soluble magnesic chloride, but only one-fourth of the potassic chloride. Three-fourths of the potash are thus obtained as a chloride, containing only one-tenth of extraneous saline matter; the remaining fourth, dissolved with the magnesic chloride in the wash-water, is returned to the boilers.

This capital process works with the utmost ease and regularity. The energetic action of the artificially lowered temperature not only dispenses with the successive eliminations which form the basis of M. Balard's method, but causes the double decomposition to take place with such intensity that the mother-liquors retain but a small proportion of sulphate of magnesia, and lend themselves with ease to the further treatment for obtaining the potash salts. Thus, when the liquid is heated in the boilers nearly the whole of the chloride of sodium separates without carrying down with it any potash; and when the double chloride is deposited by the subsequent cooling, no potash is left in the waste liquor. The whole of the potash is thus precipitated as double chloride; and, this salt being very pure, nothing more is required, in order to obtain separately the chloride of potassium, than to wash out the chloride of magnesium with cold water and to dry the residue in the centrifugal machine. A very remarkable feature of M. Merle's process is the great facility with which the chloride of sodium is obtained in a finely divided state by ebullition in the boilers. If the liquor of 1.24 sp. gr. (28° B_o) were boiled down without previous elimination of the sulphate of magnesia by the above-mentioned cooling process, crusts would form on the bottom of the boiler to such an extent as to hinder the operation greatly, if not entirely to stop it. But the double decomposition which takes place under the influence of cold, by depriving the liquor of sulphate of magnesia, and rendering it rich in chloride of magnesium, changes these conditions. Indeed, the liquor thus treated may not only be boiled down without the formation of the strongly adhering earthy deposits which would otherwise appear, but it does not even produce the slight crusts which form during the refining of rock salt; so that the preparation of the refined salt is carried on under very favora-

ble conditions. Ease and regularity are not, however, the only characteristics of this process. It is remarkable also for the large quantity of saline products which it is capable of yielding. In fact, the salt-work operation being limited to the production of a liquor of 1.24 sp. gr. (28° B.) on the ground, the loss arising from the permeability of the soil is quite insignificant, and not to be compared with the serious waste which results from this cause when the treatment of the liquor in the salt gardens is continued to much higher degrees of concentration, according to the earlier practice. In point of fact, the first stage of the treatment in the salt works, according to the original method, becomes the last stage in the improved plan. The saline water of 1.24 sp. gr. (28° B.) once transferred to the large tanks remains, during all further stages of the process, in metallic vessels; and, as the subsequent operations are conducted without loss, an amount of product is obtained which, when large evaporating surfaces are employed, may become enormous. A cubic metre of liquor at 28° B., which, if no loss occurred, would correspond to 25 cubic metres of sea-water, but which, in consequence of the loss occasioned by infiltration, is equivalent to 75 cubic metres of sea-water, yields, when treated as above described, 40 kilograms of anhydrous sulphate of soda, 120 kilograms of refined culinary salt, and 10 kilograms of chloride of potassium.

POTASH SALTS FROM THE ROCK-SALT MINES OF PRUSSIA.

We will now examine one of the most interesting and important mineral developments made for many years, and one that has produced and is producing remarkable effects upon certain of the chemical arts, deranging the commercial value of potash from other sources, and giving rise to other pursuits: it is the discovery of immense quantities of chloride of potassium in the salt mines of Stassfurt, Prussia. Like many other valuable discoveries it was made by chance, and the value of it was so little esteemed at the time that it was looked upon as a nuisance by those who had made it. It soon, however, attracted the attention of the chemist, H. Rose, of Berlin, who recognized its great value, and communicated the fact to the Prussian government; and since then these potash compounds have acquired great importance, and are being extracted in large quantities.

GEOLOGY OF THE STASSFURT DEPOSITS.

The geological formation in the district of Stassfurt has been ably described by Daubrée, and in order that the deposits of the locality may be better understood an extended abstract of his description is here given:

It is known that the salt deposits which underlie the variegated sand-stone of this locality, and which have accumulated to a thickness of about 200 meters, present differences at different depths. It is easy to distinguish four distinct levels, which, commencing at the bottom, are:

1, of anhydrite, consisting of beds of rock salt, separated by thin beds of anhydrite, 107 meters; 2, that of polyhalite, in which the beds of rock salt are separated by thin layers of this mineral, $31\frac{1}{2}$ meters; 3, that of kieserite, in which the rock salt is associated with this hydrated sulphate of magnesia, 17 per centum, and with carnallite, a double chloride of magnesium and potassium, 13 per cent.—thickness, 28 meters; 4, the carnallite, or potash salt, consisting of a double chloride of magnesium and potassium. At this level the carnallite predominates, and forms 55 per cent., the rock salt 25 per cent., and kieserite 16 per cent. In this last level is found tachydrite, a double chloride of calcium and magnesium; sylvite, a chloride of potassium; and kainite, a combination of hydrated chloride of potassium and sulphate of magnesia.

The explorations have developed the existence of a mass of carnallite equal to 6,000,000 tons of chloride of potassium. Shafts sunk over half a mile distant one from another, one at Stassfurt and the other at Anhalt, show analogous deposits. After striking the salt beds the following are the deposits passed through :

<i>At Anhalt.</i>	<i>At Stassfurt.</i>
Yellow kainite, (hydrated chloride of potassium and sulphate magnesia.)	Carnallite.
Carnallite, (chloride potassium and magnesium.)	Boracite.
Sylvite, (chloride potassium)	Tachydrite.
Sylvite, with kieserite	Red carnallite.
Kieserite, (hydrated sulphate magnesia) ...	White carnallite.
Polyhalite, (hydrated sulphate potash, lime, and magnesia.)	Kieserite.
Rock salt with anhydrite	Polyhalite.
	Rock salt with anhydrite.

The quantity of carnallite taken out of these two pits from 1861 to 1866 has gradually increased from 2,500 tons to 150,000 tons, and this quantity is worked in thirteen establishments erected for the preparation of chloride of potassium. Manufacturers are already engaged in preparing caustic potash and carbonate of potash from this chloride, and by a process similar to that employed in the manufacture of soda. The effect has been to greatly diminish the cost of potash, to disturb its production from other sources, and to extend its use even to agricultural purposes. As yet no other workable deposits of carnallite have been discovered, although it is found in small quantities in many other mines of rock salt, and there is every reason to suppose that it will be discovered in large quantities elsewhere.

It was at a depth of 280 meters that the salts of potash, soda, and magnesia were first struck.

THEORY OF THE ORIGIN OF THE STASSFURT DEPOSITS.

How can the origin of this peculiar formation be explained? Professor Balaard, who has so thoroughly studied the phenomena attendant upon the evaporation of sea-water in the salines, ventures the following explanation, which is a very reasonable one:

In evaporating the water, the first deposit contains carbonate of lime and traces of oxide of iron, and next there is produced sulphate of lime with two equivalents of water, then a layer of common salt followed by a deposit of sulphate of magnesia, and after a while potash appears and is deposited in the form of a double sulphate of potash and magnesia with six equivalents of water, then a double chloride of potassium and magnesium, all of which is finally covered with a concentrated solution of chloride of magnesia, containing the bromides, which infiltrates itself slowly into the soil.

Suppose, now, that the resulting products of this evaporation are not disturbed, and in the spring (the winter rains not having entirely redissolved the salts) a fresh quantity of sea-water is let upon this deposit, the water thus introduced, while not sufficient to dissolve all the common salt and sulphate of lime, is sufficient to dissolve the salts belonging properly to the mother-waters. This new solution, being more concentrated than that of the former year, deposits more promptly upon its evaporation a layer of sulphate of lime, which covers the undissolved salt, then a new layer of common salt, then new layers of products from the mother-waters in the order already indicated. We will suppose the same operation to be repeated for a series of years, and each year a new layer of common salt to be deposited with an intervening thin sheet of gypsum, the density and quantity of the mother-water to be constantly increasing so that the soil can no longer absorb it. Suppose now from any cause whatever the influx of sea-water ceases, but that the evaporation goes on in the mother-water, furnishing, in the order above stated, the magnesia and potash salts. If now argilaceous deposits take place over these saline beds and protect them from the action of rain water, we have, as a final result, a thick bed of common salt lying on a bed of gypsum, and interleaved with thin sheets of it, thus separating the products of each successive year, and enabling us to count the number of years taken to form the salt bed, as the rings in wood mark the years of the tree.

To attribute the origin of the Stassfurt deposit to sea-water requires us to suppose that this locality was formerly an estuary of the sea, but this is not very probable, and the supposition of Bischof is more rational, viz: that this part of Thuringia was a point where, in the course of ages, has been evaporated the concentrated waters of a soil covered with saline efflorescences, the waters brought in by a continual influx, which a change in the configuration of the surface of the country interrupted at some later period.

There is one fact to be remarked in connection with the salts as they

are found in the presumed case of evaporation in the salines, and as they occur in the salt mine, viz: that the salts in the latter are much less hydrated than in the former; the gypsum in the salines, with two equivalents of water, being replaced in the mine by anhydrite, (anhydrons sulphate of lime) and the sulphate of magnesia with seven equivalents of water in the salines replaced by the sulphate with one equivalent of water, which facts would lead to the inference that after these bodies of salts were deposited they were subjected to an internal heat which caused this diminished hydration; a supposition that is strengthened by the presence of a *magnesian boracite*, that has been called stassfurtite, the boracic acid being introduced by the eruptive phenomena, which may have also introduced hydrochloric acid vapor, giving rise to certain compounds, the formation of which is most easily explained in this way.

It must not be overlooked, however, that the evaporation of the waters under the two conditions we are contrasting must have taken place somewhat differently, and consequently the associations of the acids and bases would not be exactly the same in all cases, as the salts we have enumerated from the salt mines will show, viz: *kainite* and *sylvite*, the chemical composition of which has been mentioned elsewhere.

EXTRACTION OF THE POTASH SALTS FROM THE STASSFURT PRODUCTS.

There are five products separated for commerce from the saline materials of the Stassfurt mine. 1st, chloride of potassium; 2d, sulphate of potash; 3d, carbonate of potash, obtained from the sulphate; 4th, sulphate of soda; 5th, potash compounds to be used with manures. It must be borne in mind that common salt constitutes the bulk of the mineral from which the substances are to be separated; *carnallite* (the chloride of potassium and magnesium) is the substance relied upon for the chloride of potassium, and the general principle of separating this from its associate is about the same in all processes adopted. The saline compound as furnished from the mine contains about 16 per cent. of chloride of potassium, the remainder being chloride of magnesium (in chemical association with the chloride of potassium) and common salt. By judicious treatment with a limited quantity of water the bulk of common salt is left undissolved in a hot solution, which solution when drawn off deposits crystals of chloride of potassium, containing 80 to 90 per cent. of chloride of potassium sufficiently pure for commerce or for use in manufacturing other compounds. The mother water from the chloride of potassium is concentrated, and the remainder of the potash is deposited in combination with magnesium as the original salt, *carnallite*, which is collected and treated over again. The last mother water is a solution of chloride of magnesium, and has not yet been utilized to any great extent.

These operations are conducted by different manufacturers in different ways. None are so simple or so likely to be generally adopted as that of Messrs. Vorster and Grmeberg. They commence by purifying the raw material, detaching mechanically as much of the common salt and sulphate

of magnesia as can be done conveniently, grinding the mass to a powder, and then treating this powder not with pure water, but with the mother water arising from a previous operation. This carries off the great bulk of the useless salts in solution, leaving the less soluble saline compounds which are sought after undissolved, as the chloride of potassium and chloride of sodium, the former of which is readily separated from the latter by judicious treatment with water. The quantity of chloride of potassium now manufactured annually at Stassfurt and Anhalt is from 20,000 to 30,000 tons, of about 82 per cent. potash salt, and it finds a market in all parts of Europe. In France it sells at the rate of about \$40 a ton. It is thought by some that the production of this salt will destroy its manufacture from the mother water of salines, and interfere very materially with the manufacture of potash salts from other sources, but M. Balard has a different opinion, and his opinion on this subject possesses great weight.

SULPHATE OF POTASH.

This product is now formed in large quantities from the chloride obtained from the mines of Stassfurt, from the salines and elsewhere, by the action of sulphuric acid of 40°. But at the mines of Stassfurt, as the materials for manufacturing sulphuric acid are not to be found, this process is an expensive one; and this induced the government, owning the mines, to offer the products at a diminished price to manufacturers who would discover and employ a process of using the natural sulphates to furnish sulphuric acid to the potash. Without detailing the numerous experiments that were made, we will describe the process which has been adopted with success. It is based on the formation of the double sulphate of potash and magnesia, with the aid of the sulphate of magnesia occurring abundantly in the mines. This salt is formed by the addition of a suitable quantity of sulphate of magnesia to the chloride of potassium. But to do this it is necessary to obtain a sulphate of magnesia as free from the chloride of sodium as possible. Messrs. Vorster and Gruneberg have accomplished this successfully.

A metallic strainer with meshes of one millimetre is suspended at the surface of a mass of water, the strainer is filled with a mixture of common salt and monohydrated sulphate of magnesia, as it is taken from the mine. In a short time the salt dissolves, and the crystals of the monohydrated sulphate pass through the meshes and fall to the bottom of the vessel, for it is hardly soluble in a saturated solution of common salt. This powder of monohydrated sulphate completes its hydration and forms a solid mass at the bottom, which is taken out and can be used for forming commercial sulphate of magnesia and producing the double sulphate we are now considering. The double sulphate may have a portion of the sulphate of magnesia withdrawn from the sulphate of potash, which, with the remaining magnesia, can be at once treated by Leblanc's process for carbonate of soda and caustic soda. This method is followed in France, but in Germany the double sulphate is purified

still further by a boiling solution of chloride of potassium, which on cooling gives at first a large crop of pure sulphate of potash, afterwards sulphate of potash and magnesia, and lastly, chloride of potassium and magnesium. The two last salts are treated over again, the first can be applied to any uses desired for sulphate of potash. This last decomposition does not necessarily require the agency of heat; the use of the chloride of potassium properly directed will accomplish the same results, but it requires more careful manipulation, and a very large amount of the solution of chloride. The sulphate of potash obtained from the salt mines of Stassfurt, as well as that obtained from the salines in France and elsewhere, is principally used in the production of carbonate of potash by Leblanc's process, so extensively used and well known for the formation of carbonate of soda.

NITRATE OF POTASH.

This compound is another potash product of the mineral kingdom; it occurs in the surface soil of many tropical regions where the composition of the soil and the atmospheric conditions are favorable to its formation. The East Indies furnish the principal quantity used in the arts. A deposit of some importance has been discovered in the Clan William district at the Cape of Good Hope. The nitrate of potash is extracted by the well-known process of lixiviation, is crystallized and purified, and is used principally in making gunpowder.

POTASH FROM ORGANIC SOURCES.

EXTRACTION FROM WOOD ASHES.

It is reasonable to suppose that the production of potash from this source has reached its maximum, not simply from the increased value of the wood from which it is produced by incineration, but principally from the increased and increasing production from the mineral kingdom. At present the vegetable sources of potash are the ligneous plants of Russia and North America, the herbaceous plants of Hungary, and the beet-root products of France. The annual supply from several countries has been of late about as follows: Russia, 9,500 tons; the United States and British America, 13,000 tons; France, 2,500 tons of carbonate of potash, purer than any other in commerce. France, in producing this quantity of carbonate of potash from the beet root, furnishes from these same beet roots, 200,000 tons of sugar and 100,000 tons of molasses.

The entire annual yield of potash known to commerce is about 30,000 tons, and this, when placed alongside of 500,000 tons, which is not far from the present product of soda, shows comparatively what an insignificant part potash occupies in the arts when contrasted with soda.

The production of potash from the beet root is one of great interest in certain countries, where this plant is grown for making sugar, and there are many details that would interest the manufacturers in those

countries, but which are not yet of much interest in this country. It will suffice to state that the molasses from the beet root is not an article of consumption, therefore most of it is fermented and distilled for alcohol, and the residual liquors in the still, when evaporated to dryness and burnt, furnish potash salts, which are subsequently purified.

POTASSI SALTS FROM THE ASHES OF SEA-WEED.

It is no object here to enter into the peculiarities connected with the varieties of sea-weed incinerated for its salts, the general subdivision is into "drift-weed," and "cut-weed;" the latter of which is regularly reaped, while the former, being from deep soundings, is floated to the shore by the tide. The drift-weed is richer than the ent-weed, both in iodine and potash salts, especially the chloride. Twenty-two tons of wet sea-weed are required to produce one ton of kelp, yielding (besides iodine, bromine, and mixed soda salts) about 500 to 600 weight of commercial chloride of potassium, containing 80 per cent. of pure chloride, the other 20 per cent. being chloride of sodium and sulphate of potash. There is no new development in regard to the treatment of the kelp for the separation of its constituents, and as the working of chloride of potassium at Stassfurt is now carried on so extensively, it is doubtful whether kelp will in future have much value as a source of potash. It will be valued chiefly for the iodine it contains. In 1862, the chloride of potassium, corresponding to 46 per cent. of oxide of potassium, averaged a little over \$100 per ton, making real potash cost nine and a half cents a pound, while that from American ash costs thirteen and a half cents per pound.

EXTRACTION OF POTASH FROM THE "SUINT" OR POTASSIC SUDORATE IN SHEEP'S WOOL.

This source of potash is not known in this country, and hardly anywhere else than in a certain part of France. Potash from this source formed an article of exhibition in 1867, as well as in 1862, and as the source is a curious one, and the process of obtaining it is not generally known, there is sufficient reason for describing it to the American technologist somewhat in detail. The nature of this source of potash was reported on in 1862, for the London Exposition, by Hofmann, and free use has been made of his description.

It is well known that sheep draw from the land on which they graze a considerable quantity of potash, which, after circulating in their blood, is excreted from the skin with the sweat, in combination with which it is deposited in the wool. Chevreul pointed out that this peculiar compound, by the French called "suint," forms no less than a third of the weight of raw merino wool, from which it may be readily dissolved out by simple immersion in cold water. In coarser wools it is less abundant, and, according to MM. Manmené, and Rogelet, the potassic sudorate or suint of ordinary wools forms, on the average, about 15 per cent. of the weight of the raw fleece.

This compound was formerly regarded as a soap; doubtless because wool contains beside the suint a considerable proportion (about 8½ per cent.) of greasy matter, (Chevreul.) This grease, however, is, in fact, combined with earthy matter, chiefly lime, as an insoluble soap. The soluble sudorate is, according to MM. Maumené and Rogelet, a neutral salt, resulting from the combination of potash with a peculiar animal acid, of which little is known beyond the fact that it contains nitrogen.

At the great seats of the woollen manufacture in France, as at Rheims, Elboeuf, and Fournies, the new industry of MM. Maumené and Rogelet, is either established or in course of establishment. Their plan is to buy of the woollen manufacturers the solutions of suint obtained by the immersion of their raw fleeces in cold water; paying higher, of course, for those liquors in proportion as they are stronger; thus, for example, for the suint from a ton of wool they pay five francs, if diffused through 27 hectolitres of water, (sp. gr. 1.030;) whereas, for the same quantity of suint they can afford to give no less than 18 francs, if it be concentrated in 3 hectolitres of water, (sp. gr. 1.250;) and so in like proportion for the suint liquors of intermediate strength.

An ordinary fleece, weighing four kilograms, contains, according to MM. Maumené and Rogelet, about 600 grams of sudorate of potassium or suint. This, according to their analysis, should contain 33 per cent. of its weight, *i. e.*, 198 grams of pure potash. Of this, according to another estimate, (showing the nitre it would produce,) they appear to reckon on about 173 grams as being practically recoverable.

The wool manufacturers of Rheims wash annually 10,000,000 kilos of fleeces, those of Elboeuf 15,000,000 kilos, and those of Fournies 2,000,000 kilos—total 27,000,000 kilograms, the produce of 6,750,000 sheep. From this quantity, were it all subject to MM. Maumené and Rogelet's treatment, 1,167,750 kilos of pure potash would, according to the above ratio, be recoverable. The value of the potash, as carbonate, reckoned at the average price of American potash, would range between \$400,000 and \$450,000. The wash-water yielding it, if paid for at MM. Maumené's and Rogelet's minimum price, would cost about \$100,000. Hence it appears that the process of MM. Maumené and Rogelet may be worked on a large scale and with very ample profit. MM. Maumené and Rogelet compute that there are 47,000,000 sheep in France—nearly seven times as many as those above calculated on. And they point out that if the fleeces of these were all subjected to the new treatment France would derive from her own soil all the potash she requires; enough, they observe, to make 12,000,000 kilograms of commercial carbonate of potash, convertible into 17,500,000 kilograms (about 17,500 tons) of saltpetre; with which, as they characteristically add, 1,870,000,000 cartridges could be charged. The difficulty of collecting the wash-waters of fleeces, scoured in small numbers by the farmers all over the country, is a great bar to such an extension of the process.

The value of potash as a manure is naturally indicated by the com-

EMPLOYMENT OF POTASH SALTS IN AGRICULTURE.

position of all land plants, for they rob the soil of more or less of this constituent. As a general thing, in our rich and virgin soil there is potash enough to supply vegetation for a long time, particularly as the slow decomposition of the particles constituting the soil liberate more or less of this alkali. In Europe, however, the case is different, and every artificial means is resorted to to restore and replenish the potash of the soil. The new and abundant mineral source of potash salts has awakened the attention of agriculturists in Europe, and now the only question for solution is the best way of applying them. On this subject opinion is still divided, but it has been satisfactorily ascertained by experiments in both France and Germany that practical benefit can be derived from them. Owing to the fact that potash in the United States is too costly for agricultural purposes, and that there is no likelihood of its being resorted to at present, no details will be given of the European experiments. The chloride of potassium is the salt generally used.

CHAPTER IV.

AMMONIA, BARYTA, MAGNESIA, AND ALUMINA.

AMMONIA AND SALTS OF AMMONIA—APPARATUS FOR MAKING AQUA AMMONIA—DETAILS OF THE OPERATION OF DISTILLING—BARYTA AND ITS COMPOUNDS—PERMANENT WHITE—MAGNESIA AND THE MAGNESIA-SALTS—OXYCHLORIDE OF MAGNESIUM; ITS PROPERTY OF SOLIDIFYING—ALUMINA AND ITS COMPOUNDS—ALUMINATE OF SODA; ITS USES IN DYEING—ALUMINA—SULPHATE OF ALUMINA—ACETATE OF ALUMINA—ALUM.

AMMONIA AND AMMONIA SALTS.

But little advance has been made in the manufacture of the ammonia compounds. Ammonia is now derived almost exclusively from gas works, it being one of the products of the distillation of coal in the manufacture of gas. It is true that coal contains but very little nitrogen, not averaging over one per cent, but when it is recollected what an immense quantity of coal is used in making gas, even this small quantity of nitrogen yields in the aggregate a large amount of ammonia. In London over 1,000,000 of tons of coal are used annually in making gas, and supposing one-third of the nitrogen to enter into the formation of ammonia, this amount of coal will represent about 10,000 tons of sal ammoniac. But even this source of ammonia does not meet the demands of the arts, especially as it is largely taking the place of potash in alum and other compounds. A still larger amount of coal is used for other purposes than making gas, and in many instances is so burnt that with but little ingenuity it may be made to increase the yield of ammonia when it becomes an object. The coking furnaces would be a prolific source, and already in the Paris gas works much coke of a very beautiful quality is made in coking ovens, and the gas as well as all other volatile products are saved.

The manner of procuring ammonia from the weak ammoniacal liquors is carried on with more system and economy in the Paris gas works than in any other works I visited. In the first place the liquors are not carried over two or three hundred yards, when they are emptied into a system of vats from which they are pumped into pans and neutralized by sulphuric or hydrochloric acid and crystallized and purified; or they are conducted to a set of stills, most ingeniously devised, but which could not be fully explained without a number of drawings. It is a system of stills and condensers, so arranged that their operations are nearly automatic, where the water is treated with caustic lime, and the ultimate result is an ammonia of every variety of commercial strength and of a sufficient degree of purity to be put upon the market at once. It is in part like the apparatus figured below for making ammonia in the moist way from the ammonia salts of commerce.

APPARATUS FOR MAKING AMMONIA.

The following is a description of a form of apparatus which I devised several years ago, and with which I have made large quantities of ammonia at a very economical rate and without the slightest inconvenience to the operator. It can be made of any required size. Its construction and arrangement are clearly shown by the accompanying figure, (Fig. 4) on page 47.

REFERENCES TO THE FIGURE.

A, retort of sheet-iron with a man-hole at the end; B, feed-pipe for solution of sulphate of ammonia; C, feed-tub, (half of a barrel;) D D', washers; E E' E'', gas pipe; F F', safety tube of one-eighth inch glass tubing; G, cooling and condensing coil, placed in a 42-gallon barrel; H, traps of one-half inch block tin pipe to run off condensed aqueous

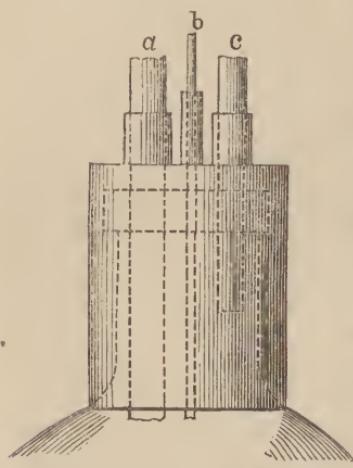
Fig. 3.

ammonia; I I', bottle No. 1; K K', bottle No. 2; L, two-gallon stoppered bottle to receive aqueous ammonia.

Fig. 3 shows the manner in which the tin cap and glass tubes are fitted on the neck of the carboy bottles I and I'. *a* is a $\frac{3}{4}$ -inch tube which reaches to near the bottom of the carboy; *b* is a safety glass tube of one-eighth of an inch; *c* is the exit tube which connects I with K.

The joints of the lead pipe are wrapped with bladder, while those of the glass or tin pipe are made with pieces of India-rubber tubing.

The tin caps on I and I' are wrapped with bladder. Those on K and K' are loose.



DETAILS OF THE OPERATION OF DISTILLING.

I. Introduce into each of the carboy bottles I I' and K and K' five gallons distilled water, unless some weak ammonia is left from previous distillation, when substitute six gallons of this in I and I'.

II. Introduce into D and D' water up to the mark X and X'.

III. Introduce into L sufficient water to cover the orifice of the trap II.

IV. Introduce into A 100 pounds fresh lime, lute the manhead in and bolt securely.

V. Having secured all the joints, allow a solution of 120 pounds sulphate of ammonia in 40 gallons water to flow from the tub C, through pipe B into A, and allow the apparatus to stand until next morning.

VI. Early in the morning proceed to distillation. By the aid of a gentle fire, the intensity of the distillation is regulated by safety tubes F F', from which none of the wash water should be ejected. If the latter occurs the fire must be damped.

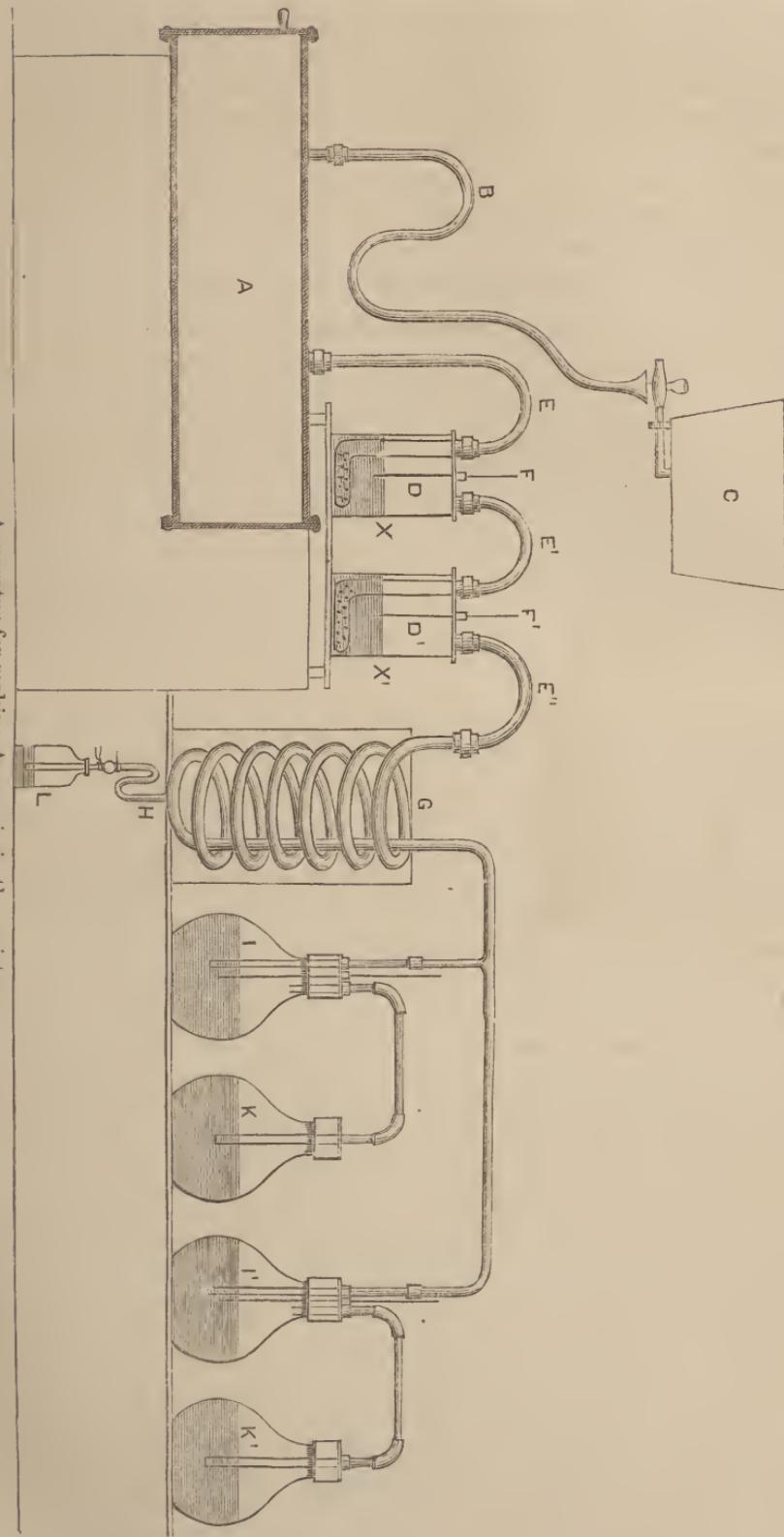


Fig. 4.

Apparatus for making Ammonia in the moist way.

VII. The cooled gas will bubble into earboys I and I', for several hours after which it works very slowly and ceases in the course of five to six hours, when they are disconnected and the block-tin pipes stopped.

VIII. From the very beginning, aqueous ammonia will accumulate in the receiver L, and this continues long after the gas has ceased to pass into the earboy. The first four gallons are generally concentrated (26°) ammonia. The next six to ten gallons will sometimes be 20° ammonia, but generally only 16°; what passes after this is weak ammonia and may be used to fill I and I' in a new operation. The distillate is collected at L as long as it smells strongly of ammonia, after which the process is discontinued.

IX. When weak ammonia has been used to fill I and I' the earboys generally contain 20° ammonia; otherwise it is between 16° and 20°, and may either be brought to 20° with the first four gallons distilled off L, or reduced with weak liquids into carboys K and K'. These latter are, however, generally not disturbed until after three or four operations, when they will generally make 16° ammonia.

X. After cooling, the contents of the retort are drawn out at the man-hole and the retort can be recharged in the manner described.

BARYTA AND ITS COMPOUNDS.

A few years ago this substance and its compounds possessed no special interest for industrial chemists; but later, their labors, especially of Kuhlmann, have brought these compounds conspicuously before the public.

Caustic baryta is not far from rivaling potash, soda, and ammonia in its caustic property, and it is not a bad substitute for potash in the chromic acid compounds. The artificial sulphate of baryta has received a special application by Kuhlmann, and he turns out two tons a day under the name of *permanent white*; but it mixes badly with oil, and has to be incorporated with white lead. The natural sulphate of baryta is very commonly used, as well known, to adulterate white lead. In the Exposition of 1867 Kuhlmann did not show that he had made any progress in his treatment, formation, or application of the baryta compounds, nor had any other exhibitor shown any of its compounds deserving special attention. The only novel application of any interest that the sulphate of baryta has received under the name of permanent white, is in the manufacture of a paper of a pure white in imitation of linen, which is used in making collars and objects of both male and female attire where the washing of such articles of linen amounts to more than their first cost when made of paper.

MAGNESIA, AND MAGNESIAN SALTS.

The only thing new in relation to magnesia compounds is the efforts to utilize more and more the chloride of magnesium, formed in the salines, especially at Stassfurt. The chloride is treated in solution with

a little less than one equivalent of lime; a double decomposition ensues, forming magnesia and chloride of calcium; this last is heated to fusion with the natural sulphate of baryta, and chloride of barium is produced, and is used to form the precipitated sulphate, the "permanent white," for the uses already mentioned.

OXYCHLORIDE OF MAGNESIUM.

Here we have an entirely novel application of the chloride of magnesium and magnesia, which, should it meet with the success that it promises, will furnish a source of consumption of much of the chloride of magnesium and magnesia which is now almost useless. M. Sorel, to whom I believe we are indebted for the invention of the process of forming a solid compound in a few minutes, by the mixture of the chloride of zinc and oxide of zinc, noticing that chemists ranked magnesium alongside of zinc, was led to examine the property of an oxychloride of magnesium formed in a way similar to the zinc compound, when he ascertained that the result was similar, viz., the rapid formation of a solid compound, but at a much less cost.

This mixture, besides possessing the property of solidifying, can become the agent of agglomerating considerable quantities of foreign substances.

The magnesia used is that obtained by calcining the carbonate brought from Greece, or that procured by precipitation from the chloride of magnesium, coming from the salines and other sources. M. Sorel mixes the magnesia with a solution of chloride, of 30° Baumé, forming a soft paste that can be molded like plaster of Paris. It is white, and resembles ivory, being slightly translucent, and it can be colored by any of the mineral colors. In twenty-four hours it becomes solid, its solidity increasing with time, finally attaining the cohesion of marble, which it resembles. It is already used in forming mosaic on marble, by first placing the desired designs on white marble with printer's ink, then corroding the surface with hydrochloric acid, afterwards filling up the depressions with the oxychloride of magnesium freshly made. Consolidation is allowed to take place, and then the surface is polished off. It is also used by Messrs. Martin & Sauvo for making a mixed mosaic of wood and cement, that has a very pleasing effect.

A conglomerate is made of one part of magnesia, 30 to 40 of sand or calcareous matter, and moistened with a solution of 25° density of chloride of magnesium. This conglomerate, it is said, can be made for \$6 a cubic yard. If all that is claimed for this cementing substance is correct, its use will be very rapidly extended for building purposes. But from all the light I could obtain from a critical examination of the substance, it is to be feared that it will not resist the atmospheric influences of moisture, &c. It is also recommended by the discoverer to use a very soft mixture of this substance to protect porous stone from the action of the weather, applying it by means of a brush.

ALUMINA AND ITS COMPOUNDS.

This class of compounds has very extensive applications in the arts. It is used in paper making to a considerable extent, not, however, to improve the quality of the paper, but rather to increase the profits of the manufacturer. It is necessary in the formation of organic lakes, and is a valuable as well as an extensively used mordant in dyeing and printing on textile fabrics.

ALUMINATE OF SODA.

This is a new product of comparatively recent introduction into the arts. Its origin is due in a great measure to the use of a mineral called *beauxite*, found in France, in the departments of Bouches-du-Rhone, and of the Var. There are one or two less acceptable localities of this mineral. This beauxite is a ferruginous mineral, containing a large amount of alumina. It contains:

Alumina	60 to 75 per cent.
Peroxide of iron	12 to 20 per cent.
Silica	1 to 3 per cent.

The aluminate of soda may be obtained by treating the powdered mineral with a concentrated solution of caustic soda, and boiling. Or it may be heated with carbonate of soda in a reverberatory furnace, and the mass when cool treated by lixiviation, and filtered by a vacuum filter, steam being used to heat the water for lixiviation, and by its condensation to form a vacuum beneath the filter. By evaporating the solution to dryness, the anhydrous aluminate is obtained in the form of a dry white powder, of a greenish tinge. As brought into commerce, it contains:

Soda	43
Alumina	48
Sulphate and chloride of sodium	9

These last come from the impurities in the soda ash, but do not interfere with the uses to which it is applied. The silica that beauxite contains remains insoluble in the form of alumina-silicate of soda. The aluminate of soda is a very infusible substance, resisting a very high temperature. It is very soluble in water, cold water dissolving as much as hot water. A concentrated solution will, however, slowly deposit alumina, leaving an aluminate with an excess of alkali in solution.

USES OF ALUMINATE OF SODA.

This substance is used to form alumina; it is also used as a mordant in dyeing, and on certain descriptions of woolen goods is said to heighten the color to a greater extent than any of the alums.

ALUMINA.

It is useless to refer to the old methods of obtaining this substance; reference will only be made to the more recent method of preparing it

from *aluminate of soda*. This is done by passing a current of carbonic acid, made in any way whatsoever, through the solution. The process used at Natrona is described under the head of soda from cryolite. The carbonic acid is passed through a long horizontal cylinder furnished with agitators. The carbonic acid completely decomposes the aluminate, and the alumina is deposited in a dense powder, if the solution is concentrated. The alumina thus obtained is now ready to be used for the formation of alum, and other uses to which this earth is applied. It, however, contains a little carbonate of soda, and can only be obtained free from it when precipitated by hydrochloric acid.

SULPHATE OF ALUMINA.

Sulphate of alumina is prepared from the alumina precipitated from aluminate of soda, and can be produced without excess of acid or the presence of any iron. The use of this substance is gradually extending in the art of dyeing and making paper. To convert alumina into the sulphate, it is put into a vessel lined with lead, with a rounded bottom, and so elevated that it can be readily emptied. Sulphuric acid is added, diluted with a quantity of water, so proportioned that with the water in the alumina there will be just the amount which is expected to remain in the sulphate. The fluid mass is rapidly agitated, in which there is no reaction at first, but in a few minutes it commences, and goes on with great vigor, so much so as to require vigorous agitation to prevent its foaming over the side of the vessel. When the reaction is over, the mass settles down and must be at once poured out by inverting the vessel. All the sulphate which is still fluid runs on to a large plate of lead with the edges turned up, when it soon becomes solid. The operation is repeated in the same vessel, and the contents are poured on to the former and cooled mass, and so on until the mass of layers is sufficiently thick, when the cake is broken up and packed to be sent to market. It contains one equivalent of sulphate of alumina and eighteen equivalents of water. It is purer and can be sold at a less price than alum, and contains a greater equivalent of alumina to the same weight, so that it must ultimately drive out, to a great extent, the use of alum in the arts.

Sulphate of alumina has very recently been formed in the province of Liege by passing the vapors formed in roasting zinc blende through immense accumulations of decomposed alum schist, formerly used for procuring alum, these accumulations being the residues of ancient works. As these conditions are, however, local in their character, no details will be given of them.

The method employed at Natrona, Pennsylvania, for forming the sulphate of alumina is the following:

For converting the alumina into a sulphate, it is added, in small portions at a time, to a boiling solution of dilute sulphuric acid of about 30° Baumé, until rather more alumina has been used than is sufficient to

form the tersulphate of alumina, the chemical formula of which is $\text{Al}_2\text{O}_3 + 3\text{SO}_3$, having an excess of alumina always present. After boiling a few hours the liquor is tested, and as it is prepared in the arts to have the proportions of a slightly basic sulphate, these are adjusted so that for each equivalent of alumina present there should be $2\frac{8}{10}$ eq. of sulphuric acid, or $\frac{2}{10}$ of an eq. less than the sulphate, as it exists in common alum. The solution is then allowed to remain at rest for some days, until perfectly clear, when it is decanted into copper vessels, and evaporated until a drop of it solidifies into a hard, brittle mass. It is then collected into leaden molds to cool, when it is packed in boxes or barrels for market. Sulphate of alumina as thus prepared is of a white, translucent color, having the hardness and appearance of alabaster. It contains mere traces of iron, and, as before said, there is present in combination also sulphuric acid, as with alumina in common alum. It also contains about 15 per cent. of alumina, or about one-half more than is present in an equal weight of common potash alum. It is on account of its basic properties, and consequent freedom from acid, its small amount of iron, its trifling cost, that, by calico-printers, sugar-refiners, paper-makers, &c., it is consumed in immense quantities.

Sulphate of alumina of this character can be prepared only from alumina obtained from cryolite, as that prepared from alum, clays, or other sources of alumina, cannot be free from a great excess of acid, which undoubtedly destroys its usefulness for many purposes and injures it for the arts.

ACETATE OF ALUMINA.

Instead of making this salt as formerly by a double decomposition between acetate of lead and alum, it is now formed by dissolving precipitated alumina in acetic acid, care being taken, however, to use alumina precipitated by hydrochloric acid, as that precipitated by carbonic acid retains a small amount of carbonate of soda, which impairs very materially its solubility in acetic acid.

ALUM.

The different forms of alum for some time in use are still employed as potash alum and ammonia alum; the latter has, however, superseded to a great extent the former, as it can be manufactured more cheaply. In England more than one-half the alum manufactured is ammonia alum, about 8,000 tons of it being manufactured annually in the different works in that country.

CHAPTER V.

CHLORINE, FLUORINE, MANGANESE AND CARBONIC ACID.

HYDROCHLORIC ACID PRODUCED IN THE MANUFACTURE OF SODA-ASH—GOSSAGE'S PROCESS OF CONDENSATION—MERLE'S PROCESS—PRODUCTION OF HYDROCHLORIC ACID AND SILICATE OF SODA—ARSENIC IN HYDROCHLORIC ACID—RECEPTACLES FOR THE ACIDS—CHLORINE, ITS PRODUCTION FROM HYDROCHLORIC ACID BY MANGANESE—RECENT IMPROVEMENTS IN THE MANUFACTURE—DUNLAP'S PROCESS—SCHLOESING'S—LAUREN'S—PROCESS BY CHROMATE OF LIME—CHLORIDE OF LIME; METHODS OF PREPARATION—CONDENSING CHAMBERS—UTILIZATION OF THE RESIDUES FROM THE MANUFACTURE OF CHLORIDE OF LIME—FLUORIC AND FLUOSILICIC ACID—GLASS FROM CRYOLITE—MANGANESE COMPOUNDS—MANGANATE OF POTASH USED IN BLEACHING—CARBONIC ACID, AND METHODS OF PREPARING IT FROM COAL.

HYDROCHLORIC ACID.

In the manufacture of soda-ash immense quantities of hydrochloric acid are produced, and formerly it was allowed to escape into the air or was condensed by water and passed into streams. The immense injury done to the lands in the neighborhood of the works, as well as to the water courses, have caused stringent sanitary regulations to be imposed on the soda factories. In England, from being very lax, they have become exceedingly stringent, and the present law requires that the hydrochloric acid should be condensed to the extent of ninety-five per cent. of the common salt used, and a rigid inspection makes the law efficient. In France, as much, until 1866, as one-half the acid escaped into the air, when the improvement of the construction of the furnaces rendered the condensation of the acid more perfect; and the interest of the manufacturers now acts more strongly than rigid laws to enforce the condensation of the vapors of the hydrochloric acid.

GOSSAGE'S PROCESS OF CONDENSATION.

There are several methods of bringing about the condensation of the acid gas, but that by means of stacks filled with coke or quartz pebbles is almost exclusively employed, and was originally used by M. Gossage. It is now extensively used in France, where three square stacks are used 18 metres in height and 1.20 meters square, constructed of sandstone or of bricks soaked with tar and filled with coke to one-eighth their height. After the gas has traversed five vats of compact sandstone, where the first condensation is effected, the gas passes in at the bottom of the stacks and ascends, encountering water that falls in a shower from above downwards; each stack has a small chimney, through which only a minute quantity of the uncondensed hydrochloric acid passes out.

Kuhlmann, and some others, condense the gas in a great number of

earthenware bottles. Kuhlmann uses as many as 250 vessels, each having a capacity of about twenty gallons; they are so arranged by a system of connections that the gas passes in one direction and the water in the opposite, and the condensation takes place at the surface, without the plunging of any tube beneath the surface of the liquid. The gas is finally passed into a vault underneath the works and is completely condensed by fragments of chalk.

MERLE'S PROCESS.

In the establishment of M. Merle, of Salindres, a mixed system is employed, condensing perfectly 95 per cent. of the acid produced. This system as described by M. Balard, who recommends it very highly, is as follows: This system of condensation is composed of two large earthenware vessels placed near to each other, in which the acid passes successively from one to the other; after these two vessels, there are two parallel rows of stoneware carboys of fifty gallons each, and these in their turn are followed by a single row of thirty carboys, at which distance the condensed gas occupies less volume. These carboys, are connected by elbows to which are joined two tubes of stoneware one meter long, giving to the combination the appearance of organ pipes, like the system of condensers in gas-works, all of which tend to cool the gas and render the condensation more speedy. The excess of gas passes to a conductor of stoneware tubes of 80 centimeters in diameter, the elements of which are maintained in a vertical position by a wooden structure; these tubes are filled with hollow stoneware balls, having a number of holes; this part of the condensing apparatus is nine meters in height and suffices for the nearly complete condensation of the gas, when water is introduced in proper quantity. This mixed system furnishes liquid acid of the density of 21°, avoiding the necessity of the manipulation of pumping the acid up into stacks, to be acted on several times by the acid gas before the requisite condensation is secured, viz., 21°, which is that required for the manufacture of chloride of lime.

There are other methods used for condensing the acid when there is no object to save it; by passing it into galleries containing limestone before it reaches the chimney which produces the draft. Tessier passes it through a lime kiln before it comes to the chimney, as the hot lime absorbs it more rapidly. In some places near the sea-shore the sea water is allowed to enter into galleries and the acid is condensed by the water.

PRODUCTION OF HYDROCHLORIC ACID AND SILICATE OF SODA.

It has been known for some time that the vapor of water will decompose common salt when they are heated together at the temperature of volatilization of the salt in connection with silica. In practice this operation is carried on by M. Gossage, not, however, for obtaining hydrochloric acid, but for obtaining silicate of soda used by him in the production of

a certain kind of soap. His apparatus is composed of a kind of cupola filled with coal, and from which escape currents of flame; it is a kind of generator of combustible gases. The flame plays over the surface of a reverberatory furnace containing common salt; this salt evaporates and passes off with the vapor of water that is injected into this furnace. The mixed heated vapors pass to a descending column filled with fragments of quartz; decomposition takes place, hydrochloric acid is liberated, the soda combines with the silica, and the silica of soda descends to the bottom of the column. This silicate of soda is used by M. Gossage for the formation of soap. It can also be decomposed by carbonic acid and furnish carbonate of soda. Hydrochloric acid is produced in large quantities; but as yet it is not collected or turned to any practical use.

ARSENIC IN HYDROCHLORIC ACID.

In hydrochloric acid prepared by arsenical sulphuric acid arsenic is sure to be found, and in some instances as much as half of one per cent. has been found. It can only be got rid of by the agency of hydrosulphuric acid.

RECEPTACLES FOR HYDROCHLORIC ACID.

The acid once formed, it becomes necessary to keep it in recipients before using it. Glass and earthenware carboys are commonly used, but latterly gutta-percha jars have been extensively substituted.

USES OF HYDROCHLORIC ACID.

The uses of this acid are principally confined to the production of chlorine; the other uses are insignificant compared with this. These uses are for dissolving the phosphate of lime from bones; in the manufacture of bicarbonate of soda; in certain operations in the bleaching of cotton; to form chloride of tin, chlorate of potash, sal ammoniac, &c., and it has been used in the production of phosphorus.

CHLORINE.

The common method of producing chlorine is still in use, viz: the reaction of hydrochloric acid on binoxide of manganese. In this, however, one-half of the acid remains combined with the manganese. This is of no material consequence when the acid is abundant and cheap. In some factories sulphuric acid is used to react on common salt and binoxide of manganese. This last substance, of course, forms a conspicuous part in this manufacture, and a good article is greedily sought after. Fortunately it is furnished in all parts of the world; among the best supplies to be found in the market are those coming from certain mines in Germany, Spain, and Nova Scotia. A very good article has also been obtained in California. There have been various processes proposed to form chlorine without the binoxide of manganese, but none of them

have been brought into practice or deserve any special notice, except Dunlap's, already referred to, under the head of sulphuric acid, and which is described more in detail a little farther on; also Schloesing's process, where he uses binoxide of manganese with a mixture of hydrochloric acid and nitric acid. Both of these processes were known more than five years ago, but are not familiar to most of those who may read this report.

RECENT IMPROVEMENTS IN THE MANUFACTURE OF CHLORINE.

In the manufacture of chlorine, the more recent improvements are confined to the vessels in which the decomposition is carried on. Two kinds of vessels are employed in France. In some establishments the vessels are made of sandstone cut out of a single piece, and holding about 250 gallons. These are encased in masonry, and are heated by steam that circulates between the masonry and the vessel, and which completes the decomposition by a jet thrown into the interior. There are some objections to this plan of heating. The jet of steam dilutes the contents of the vessel too much, so that latterly they have returned to the use of vessels of stone-ware, of fifty to sixty gallons capacity, furnished with a lateral opening, by which the chloride of manganese can be drawn off with a siphon and fresh acid introduced. These vessels have a large opening, in which a cylinder of forty centimeters diameter (perforated with holes) can be introduced. These cylinders are filled with manganese in small lumps, and they are introduced only partially into the acid, so that all the manganese is not moistened by the acid, but as the manganese is gradually dissolved, it descends until all of it is acted on. The cover of the large opening has a hole in it, with a lead tube adapted to it for carrying off the chlorine. These decomposing vessels are introduced in groups of four into a rectangular chamber of masonry, open at the top, which is afterwards covered with boards on which dirt is thrown; steam is made to circulate around the vessels, and they are heated as high as 90° Cent.; by this process six or seven per cent. of the acid remains undecomposed. In Lancashire large vessels are used made of six thick Yorkshire slabs joined by grooves at the edges, luted with a cement that will resist heat, and bound by bands of India-rubber, and held together by iron bolts and nuts. They have the necessary openings for charging and cleansing, and are of very large dimensions, taking for a single charge from four hundred to eight hundred pounds of oxide of manganese. They are heated by steam, and the gas is carried off first by lead pipes, and, as the gas cools, by gutta-percha tubes.

DUNLAP'S PROCESS OF MAKING CHLORINE.

Reference has been made to Dunlap's method of forming chlorine for manufacturing purposes, without oxide of manganese. I will give Hofmann's description of it, as he saw it carried out at the works of Tennant & Co., of Glasgow. It consists in decomposing a mixture of chloride

of sodium and nitrate of soda by means of sulphuric acid. The products of the reactions are chlorine, nitric acid, and sulphate of soda; the two volatile products being separated and employed respectively for the manufacture of chloride of lime and sulphuric acid.

The operation is conducted in large cast-iron cylinders lined with bricks set in coal pitch. These cylinders are five or six feet in diameter, and from seven to eight feet in height, capable of holding half a ton of nitrate of soda and a ton of common salt, together with the quantity of sulphuric acid necessary for the conversion of the nitrate and chloride of sodium into sulphate. The vessels are heated over a naked fire to a temperature varying between 200° and 250° C.; in thirty-six hours the reaction is complete. The gases as they leave the apparatus consist of chlorine and nitrous acid, with a little hydrochloric acid; these are conveyed into large leaden vessels, containing sulphuric acid to the height of about two feet. These acid holders are placed one after the other, and the gases are compelled to pass through them successively under a considerable pressure. The sulphuric acid absorbs the nitrous acid, and when sufficiently charged, is employed in the leaden chambers to furnish directly the nitrous acid to the sulphurous acid, the nitro-sulphuric acid being thus advantageously employed, the remaining mixture of chlorine and hydrochloric acid then passes into a small condensing tower full of coke moistened with water. The hydrochloric acid is thus retained, when the purified chlorine passes on to the chloride of lime apparatus. The residue of bisulphate of soda in the cylinders is either employed to decompose the nitrate of soda in the preparation of nitric acid, or else cast into the sulphate of soda furnace with chloride of sodium, from which it expels hydrochloric acid, being itself converted into neutral sulphate of soda.

The above method of Dunlap is only used by the Messrs. Tennant & Co.

SCHLOESING'S PROPOSED METHOD OF MAKING CHLORINE.

The proposed improved method of Schloesing is based on the fact that when peroxide of manganese, prepared by heating nitrate of manganese, is acted on by a mixture of hydrochloric and nitric acids at a certain degree of concentration, the application of heat produces chlorine and red nitrous fumes; below this point of concentration the mixture may be heated to ebullition without giving off anything but chlorine, the nitric acid combining with the protoxide of manganese to form the nitrate, and the hydrochloric acid alone is decomposed, furnishing chlorine. The practical operation is accomplished by using nitric acid containing 50.5 grams of anhydrous acid to the litre, and hydrochloric acid containing 397 grams of hydrochloric acid to the litre, mixing these acids in the proportion of four equivalents of nitric to four equivalents of hydrochloric acid, and adding to the mixture one-seventh of its volume of water.

The nitrate of manganese formed is decomposed by heat at 190° C.,

the decomposition is rapid, and the nitrons acid formed may be passed into sulphuric acid chambers, or reconverted into nitric acid by contact with air and water. The reaction appears to be a very pretty one, but as yet has not been put into practice.

OTHER METHODS OF PRODUCING CHLORINE.

There is a method recently proposed in Belgium, by first converting sesquioxide of iron into the sulphate by the direct action of sulphuric acid, then mixing this sulphate of iron with three equivalents of chloride of sodium, heating the mixture in dry air, when chlorine is evolved.

Lamrens's method has been revived by M. Mallet, viz, *producing chlorine from chloride of copper*. He proceeds as follows: Upon protochloride of copper heated to 100° or 200° C., commercial hydrochloric acid is slowly dropped, steam alone will be disengaged, and supposing the addition of acid to be slow enough and the access of air and renewal of surface sufficient, the odor of hydrochloric acid will be scarcely perceptible, and the whole protochloride will be transformed into anhydrous bichloride, which, when heated in a close vessel, instantly disengages chlorine, with the reproduction of protochloride that can be again put through a second, third, or any number of processes with but small loss of the original matter. In this way 100 kilograms of chloride of copper can be made to produce from 200 to 300 kilograms of chloride of lime, in twenty-four hours. The price of the raw material does not exceed one franc the kilogram. This process, although not yet in practical operation, has evidently a future application.

There is also another process, having a promise of good results hereafter, the formation of chromate of lime by the *action of the oxide of chromium on lime* at a red heat, and the subsequent action of hydrochloric acid on this chromate, when chlorine is formed; the reproduction of oxide of chrome from the residue, by treatment of the solution with milk of lime, and the reaction a second time, and so on.

All these processes, while they do not yet compete with the oxide of manganese process, show that we have not anything to apprehend from the rise in the price of manganese.

USES OF CHLORINE—CHLORIDE OF LIME.

This element, although applicable to so many useful purposes in the arts, from its gaseous nature, cannot be stored away, as *chlorine*, for transportation. Fortunately, hydrated lime becomes a convenient and cheap medium by which it can be condensed, and, by subsequent operations of a very simple character, made to develop its useful properties. The chloride of lime formed by this process is so well known, and the process of its manufacture is so thoroughly described, that very little will be said upon it, especially as there was nothing special connected with its manufacture brought out by the Exposition.

LIME FOR MAKING CHLORIDE OF LIME.—It is probably not well under-

stood how important it is to select the proper kind of lime for the manufacture of chloride of lime. A pure lime is not the best; a small quantity of silica and alumina in the lime is an advantage, from some unknown cause, and the limestones of some localities are preferable to those from others. There is no better way of ascertaining the best quality for this purpose than by direct experiment. There is a certain quality of limestone near Rouen, in France, so well adapted to this purpose, that the vessels from England, bringing coal to Rouen, take back to Newcastle this limestone, to be used by the manufacturers there.

CONDENSING CHAMBERS.—The forms of chambers used for combining the chlorine with the lime are various, although lead chambers are coming more and more into use; but there is none better than the one very commonly employed in England, viz., chambers in the open air, constructed of bricks, cemented, and made solid and substantial, with a roof that sheds the water during rain. The floor of the chamber is covered with slackened lime to the depth of about seven inches, with a height of eight or nine feet to the ceiling, which is slightly arched; there are glass windows in it, to examine the operation, and to judge by the permanency of the yellow gas that the chlorine is no longer absorbed. The lime is never agitated, and the operations are carried on slowly, and last during four days. There are two large openings that are well closed with wooden doors, covered with pitch, and are opened at the end of the operations to drive out the excess of gas, and to withdraw the lime, or introduce casks, that in winter time, during the bad weather, are filled inside of the chamber.

SPONTANEOUS ALTERATION OF THE CHLORIDE OF LIME.—It unfortunately happens that this compound undergoes more or less alteration by time, which is accelerated by an elevated temperature, producing chloride of calcium and chlorate of lime. Something analogous to this sometimes takes place in the chambers. At 100° C. chloride of lime will liberate chlorine and oxygen; the temperature, however, in the chambers seldom exceeds 50° C. A very rapid introduction of the chlorine may raise some parts to 100° C., but this is rapidly cooled down by the contiguous lime, so that no injury to the lime may ensue. It sometimes happens that after the chloride of lime is packed violent reactions take place in the interior of the mass, raising the temperature far above 100° C., decomposing the chloride to such an extent as to render it useless. It generally happens that chloride of lime of this character will indicate its true character if properly inspected before packing.

The causes of this decomposition are not understood, but those who exercise certain precautions never suffer loss in this way. These precautions are: First, the chlorine gas is thoroughly cooled, thus condensing moisture and hydrochloric acid. In certain English works this cooling is accomplished by passing the chlorine through a tube several hundred yards long. Second, incomplete hydration of lime. To avoid this, never use the lime the day it is slackened, but let it lay over two or three days.

Some of the best-directed establishments never use the slackened lime under eight days, and then even bolt the lime. When these two precautions are observed, there is no fear of failing to make an unalterable chloride of lime.

UTILIZATION OF THE RESIDUE OF THE MANUFACTURE OF CHLORIDE OF LIME.

The residue of the manufacture consists of chloride of manganese with a little free hydrochloric acid. When this last is neutralized by lime it can be used with great advantage in disinfecting cesspools, &c. It has also been used by Kuhlmann to form chloride of barium, by acting on the natural carbonate of baryta. This chloride is subsequently employed for furnishing sulphate of baryta, which is largely used, mixed with soluble glass, for a certain style of painting. It has also been proposed to precipitate it by lime and form balls out of the mass, and mix with iron ore to form spiegel iron, now used so largely in the formation of steel by Bessemer's process.

But the most important use to which the residue is put is the reproduction of the peroxide of manganese. The first operation in this case is to form the carbonate of manganese; this is done by using the milk of lime, adding just enough of it to neutralize the excess of acid and precipitate the peroxide of iron that is contained in the solution. After the liquor has been well agitated and subsequently settled, it is pumped into a large cylindrical boiler that can be perfectly closed and has an agitator. To this a milk of finely divided carbonate of lime is added in sufficient quantity to precipitate the manganese, carefully avoiding an excess. The boiler is closed, and heat applied, either by fire or steam, until the pressure in the boiler reaches two to two and a half atmospheres. In about twenty-four hours the operation is complete, and a white precipitate of carbonate of manganese is formed; the precipitate is washed, pressed, and dried on iron plates. The conversion of the carbonate into peroxide is effected by placing the carbonate in shallow sheet-iron vessels upon wagons that are run upon rails into vaulted galleries of brick-work. At the establishment of Messrs. Tennant & Co., of Glasgow, the galleries are large enough to hold forty-eight of these wagons. The galleries are heated from the outside, and are raised to a temperature of 315° C.; a current of air traverses the galleries, under the influence of the heat that increases as the wagons descend. The manganese loses its carbonic acid, and the oxygen of the air combines with it, care being taken to sprinkle the manganese with water as it descends in the galleries. After remaining about forty-eight hours, the compound contains eight-tenths pure peroxide of manganese and two-tenths of lower oxygen compounds of manganese, and is said to rival in efficiency the native oxide. This process has not been generally adopted, because the apparatus and manipulations are expensive and the native oxide is usually cheap.

Another utilization of the residue is to evaporate it to a sirup-like con-

sistency and mix with it nitrate of soda—79 parts of chloride of manganese to 106 of nitrate of soda. This mixture, dried at a moderate temperature and heated in iron cylinders to a low red heat, evolves nitrous fumes, which may be used in the sulphuric acid chambers. The residue consists of peroxide of manganese and chloride of sodium, which can be employed directly in making chlorine, but this has not given very satisfactory results in practice.

Paul Buquet, director of the works at Dieuze, Kopp, and others have applied the chlorine residue to the reproduction of sulphur from soda residue. This industry has been fully reviewed in the chapter upon sulphuric acid; but it is proper to give some details of the process as carried on in the establishment of Dieuze, where the chlorine residue is employed for this purpose. It consists in making as intimate a mixture as possible of the soda residue and a small quantity of the chlorine residue, deprived of its free acid by lime; seven or eight litres are sufficient for 100 kilograms of soda residue. There is a sulphide of manganese first formed, which, in contact with the air, is decomposed, forming oxide of manganese and sulphur, which last combines with the sulphide of calcium.

At Dieuze the mixture alluded to above is placed in a large heap of about 400 cubic feet, the height being about six feet. The reaction commences in about three days after the turning up of the mass; heat is developed, and the mass dries, when it must be sprinkled to keep it moist. At the end of six days in summer and nine days in winter they proceed to lixiviation in large brick basins, with a false bottom pierced with holes. The mass is well washed, and the washing and filtrate so managed that by passing through a series of vats, alternately, a saturated solution is obtained of polysulphide of calcium, with but a very little hyposulphite. The insoluble portion in the vats is exposed a second time to the air and relixivated; this contains also polysulphide of calcium, but with a large excess of hyposulphite. These two solutions are called "yellow water;" the first, however, goes by the name of "yellow sulphur water," and the second "yellow oxidized water." These are both decomposed by the chlorine residue containing protochloride of manganese, perchloride of iron, and free hydrochloric acid, in large stone-ware basins, the joints of which are luted with pitch. Both solutions must be clear when brought in contact. The first action by the free acid is to precipitate sulphur, which becomes more or less mixed with sulphide of iron and other impurities. At this point no more of the yellow water is to be added; this is known by the solution becoming black with the sulphide of iron. The precipitate is raked out and used in making sulphuric acid, or purified, when every cubic yard yields about 100 pounds of sulphur. Second, the manganese liquor is still continued to be treated with the yellow waters until the precipitate formed is no longer blackish, but has the flesh tint of sulphide of manganese, when the liquor is allowed to repose and the pure manganese liquor is drawn off clear. The yellow water is further

added until the precipitation of the manganese is complete, the precipitate here being sulphur and sulphide of manganese. The only residues that are now to be thrown away are those left by the first lixiviation, not deleterious, and chloride of calcium, which is also innocuous. The mixture of sulphur and sulphide of manganese, equivalent to 58 per cent. of sulphur, can be burned directly in the sulphur furnace of the sulphuric acid chamber. It must be dried carefully and used at once, as it is apt to ignite spontaneously from the decomposition of the sulphide of manganese. From the combustion, sulphate and some of the lower oxides of manganese are produced. Some application has been made of these substances, but the results, while promising, have not, as yet, amounted to any good practical success. The oxides, however, are quite pure, and can be used by glass-makers and others.

At Dieuze the system of apparatus is complete and perfect, and they now regularly recover 36 per cent. of the sulphur used in their chambers for producing sulphuric acid. This and similar triumphs of the skill and perseverance of the chemists of the present day give a clear idea of what the industrial arts are to expect from them in the future.

Besides making chloride of lime, the industrial uses of chlorine are limited. It is used to make chlorate of potash, in the manufacture of which there has not been any improvement since the well-known method of Graham was devised of forming chlorate of lime. It is also used in making per-chloride of tin.

GENERAL REMARKS ON THE EMPLOYMENT OF SODA AND CHLORIDE OF LIME.

These two substances are intimately associated with the wants of civilized society. The soda furnishes glass and soap, and other necessaries of life. The chloride of lime is now absolutely necessary for nearly all bleaching operations, and its use in paper making increases every day. The use of these two substances mark in some sense the progress of civilization. In England the quantity of salt used in making soda and chlorine in 1867 was 400,000 tons, and for the same year in France 107,000 tons; and the soda salts of 80° produced cost in London \$42 the ton, and in Paris \$52.

FLUORIC AND FLUOSILICIC ACID.

The production of these acids on an industrial scale formed a somewhat prominent feature in the development of the chemical arts as brought out by the Exposition of 1867. Up to the present time fluoric acid and the compounds of fluorine have had only a limited application in the arts; but M. Tessié du Motay and others have recently done much to extend their use.

The experiments of Tessié du Motay are based on the decomposition of fluor spar mixed with silica and carbon, and the formation of fluoride of silicon. The manner of conducting the operation is to make a mix-

ture of fluor spar, silica, and alumina in such proportions as to form a slag similar to that formed in an iron blast furnace, and to add to this a suitable quantity of carbon in the form of powdered charcoal or coke. This mixture, slightly moistened, is made into bricks, which are dried in an oven, and are afterwards, with a sufficient quantity of coke, thrown into a blast furnace thirty or forty feet high, already heated up by coke. As the charge descends it is decomposed by the heat, the silica and fluoride of calcium are decomposed, the carbon aiding by abstracting oxygen from the silica, the resulting compounds being fluoride of silicon and silicate of calcium; the former passing off in the form of gas, the latter uniting with the alumina, and running off in the form of a slag. Thus nearly all the fluoride of calcium is decomposed, the balance passing off with the slag. A properly arranged apparatus is placed above the mouth of the furnace in order to collect the gas, which is conducted into a series of five condensing chambers constructed of wood and containing a large number of plates of glass inclined like Venetian blinds and moistened by the sprinkling of water on the surface, which decomposes the fluoride of silicon, forming silica, which is deposited in the bottom of the chamber, and fluosilicic acid, that is dissolved by the water. The water supplied to each chamber is taken from the chamber just below in the series; thus number five supplies number four, and number four supplies number three, and so on; this is done for the purpose of concentrating the acid as much as possible, which, however, never goes above 10° Baumé, and more commonly not above 5°. The acid thus made costs four times the price of its equivalent quantity of sulphuric acid. This acid is doubtless calculated in time to be applied to many useful purposes in the chemical arts; it has been for some time employed in making chloric acid from the chlorate of potash, for compounding with other bases to be used in the pyrotechnic art. The most extensive purpose had in view in its recent production on a large scale, is to decompose the chloride of potassium, (now so abundant,) and the formation of the insoluble fluosilicate of potash. To accomplish this, a saturated solution of chloride of potassium is made in wooden vats, and 100 litres of fluosilicic acid of 5° Baumé is added for every seven kilograms of the chloride of potassium in solution. A bulky precipitate is formed of fluosilicate of potash, which is separated from the water that now contains hydrochloric acid, and is collected on felt filters and finally on heated bricks. Thus prepared, it is introduced into commerce and sells in France at ten cents per pound. It is often used in the place of borax, and can be substituted for it in making flint glass. It can also be used for the formation of caustic potash, by first decomposing it in gas retorts by applying heat. Fluoride of silicon is driven off, and can be condensed for another operation, and fluoride of potassium remains behind, which can be decomposed by lime or its carbonate, forming caustic potash, or carbonate of potash, and fluoride of calcium, that can be used in a subsequent operation. This process can be applied to soda

salts also; and Tessié du Motay has commenced the manufacture of these compounds on a large scale.

The use of fluorine compounds has been considerably developed by the same inventor, in connection with M. Maréchal, in *engraving on glass*; fluoride of an alkali with sulphuric acid being employed to engrave glass without destroying the polish, and employing a hydrofluate of the fluoride of silicon when a dead surface is desired: these methods of furnishing the hydrofluoric acid are but a modification of known processes. We are doubtless to expect something in the future from the introduction of these compounds in the arts. Already cryolite, the natural fluoride of aluminum and sodium, is being largely applied in the manufacture of an opaque glass, and it is desirable to present, in some detail, an account of the process as described in the American Journal of Pharmacy, May, 1868:

GLASS FROM CRYOLITE.

"The application of cryolite to this new porcelain or opaque glass promises to be one of those discoveries, simple in themselves, that may materially affect the course of trade and manufacture. This material (which is simple glass, so far as the mode of working is concerned) is furnished at less than the cost of the cheapest ordinary white or flint glass. It can be worked or formed with the facility attending working common brown or pressed glass, and any article of any shape that can be made from glass can be made from it, and the product exactly resembles the finest French porcelain in appearance and beauty, but far surpasses it, as well as glass, in toughness, strength, and capability of standing sudden changes of temperature. The ingredients used in its manufacture consist of cryolite 10 pounds, white sand 20 pounds, and oxide of zinc 5 pounds; the dirty discolored oxide, worth less than half the price of the white oxide of commerce, answers very well for this purpose. The infusion of the ingredients is effected at the same heat, and in the usual manner practiced in the flint-glass factories. In this manner can be made not only the articles ordinarily made of glass or porcelain, but also tiles, mantel-pieces, moldings, statuary ware, mortars, pill tiles, evaporating dishes, funnels, ointment jars, and, in fact, any and everything capable of being cast, blown, or molded whilst in a melted state, and at a mere trifling cost. The business of making these articles from cryolite is as yet in its infancy. One establishment in this city alone, [Philadelphia,] and the only one yet in operation, is working exclusively on it, consuming from 500 to 1,000 tons of cryolite per annum; but its use will necessarily become general, either as a specialty or in connection with the ordinary white or transparent glass. Having obtained from the factory of this 'hot-cast porcelain' several mortars, funnels, and evaporating dishes and tested them fully and satisfactorily, they were found to have their advantages over the ordinary ware now in use. The mortars presented at all times a much whiter color, and withstood more pounding

or trituration than the Wedgewood mortar commonly used; and the evaporating dishes resisted the heat of both the sand and water baths; at the same time we were able to purchase them at about one-half the cost of ordinary porcelain. Not only these bulky and useful articles are manufactured, but also the finest parlor ornaments and lamp shades are made and decorated, and finished in a most beautiful manner, at the establishment which is situated in the upper part of Kensington, on York avenue, in Philadelphia."

MANGANESE COMPOUNDS.

Until comparatively recently, the natural compounds of manganese were only to be seen in industrial chemistry, and were used for the manufacture of compounds requiring a certain supply of oxygen. In 1862, the visitor to the London Exposition saw the manganates and permanganates produced on a large scale by several chemical factories; this arose principally from M. Condé's successful introduction of these substances as powerful disinfecting agents, especially in rendering water charged with organic matter, and even foetid, fit to drink, all that was necessary being to introduce a small quantity of a solution of these salts until the water was permanently but slightly colored by the salt.

The present Exposition furnishes us with the important results of M. Tessié du Motay in forming manganate of potash or soda by passing air over a mixture of oxide of manganese and the caustic alkali. This has been used for forming oxygen cheaply and on a large scale; and it will be referred to in another part of the report.

MANGANATE OF POTASH, USED IN BLEACHING.

In many instances in bleaching tissues, even after the successive treatment of the alkalies and chloride of lime, exposure to the action of light is requisite. In this, as well as in all other cases, the result can be immediately accomplished by the permanganate of soda; the operation is as follows:

Mix green manganate of soda with a certain quantity of sulphate of magnesia. This can be dissolved when required, as it furnishes a red solution—the permanganate; into this the tissue required to be bleached is immersed for from four to ten minutes. It is now withdrawn, and has a brownish color, arising from precipitated peroxide of manganese; it is washed by immersing it in a weak solution of sulphurous acid, which reduces the deutoxide of manganese with the formation of the sulphate of manganese; it is subjected to this operation two or three times, when the tissue becomes perfectly white. If the practical operation of this process proves a success, we will have another most important step in the art of bleaching.

CARBONIC ACID.

This acid, so abundant in nature, has not occupied a conspicuous position in technical chemistry, principally from the fact of its being a feeble

acid. It is, however, coming more into use for certain operations. Convenient and cheap methods are therefore sought for forming it more or less pure, as in making aerated waters and getting rid of the lime in the defecation of sugar.

CARBONIC ACID FROM THE COMBUSTION OF COAL.

It can be produced by passing air over incandescent coal, or by heating limestone, or by acting on the carbonates with the strong acids. The former is, however, the method most commonly employed for making it at the sugar factories, and is considered the cheapest. Coke or charcoal is burnt in a close furnace, and the gaseous matter resulting from the combustion is washed by passing it through water, and ultimately introduced where it is required. The acid thus made of course contains a large amount of nitrogen. Very recently we have a method proposed by M. Ozouf, which furnishes the gas quite pure; it is based on the capacity of a solution of carbonate of soda to absorb carbonic acid and to disengage it when heated.

OZOUF'S PROCESS.

Air which has been passed over ignited coal by means of a pump is driven through a solution of carbonate of soda, and after the absorption ceases, this soda is introduced into a kind of still and heated; pure carbonic acid is driven off; the solution returns to its original condition, and is ready to be recharged with carbonic acid.

The apparatus is said to be costly, amounting to about \$6,000 or \$8,000, but it can produce carbonic acid at a cost of two cents the cubic yard. It is said to be already used in the manufacture of white lead and aerated waters.

CHAPTER VI.

INDUSTRIAL PRODUCTION OF OXYGEN, HYDROGEN, AND OTHER ELEMENTS.

OXYGEN AND ITS PREPARATION ON A LARGE SCALE—PROCESS OF DE MOTAY—HYDROGEN; ITS PREPARATION BY GIFFARD'S PROCESS—PHOSPHORUS AND ITS COMPOUNDS—FRICTION MATCHES; INCREASE OF FIRES CONSEQUENT UPON THE USE OF—PHOSPHATE OF POTASH AND PHOSPHATE OF SODA—BROMINE; ITS INCREASING IMPORTANCE IN TECHNICAL CHEMISTRY—IODINE; IMPROVEMENTS IN THE PROCESSES FOR PRODUCING—SODA-NITRE BEDS OF PERU A SOURCE OF IODINE.

OXYGEN.

Ever since the composition of our atmosphere was clearly understood, it has always been a problem among chemists to obtain the 21 per cent. of oxygen contained in it in a pure state, so as to render it more available for the vast variety of purposes to which it might be applied. There have been various manufacturing processes devised by Boussingault, by St. Claire Deville and Debray, by Tessié du Motay, Maréchal, and others; one using baryta, and depending on the absorption of oxygen at one temperature and the liberation of it at another; the second looking to the decomposition of sulphuric acid by heat into oxygen and sulphurous acid; the third, the absorption of it from the air by a mixture of oxide of manganese and soda at a certain elevated temperature, and the liberation of it by the action of super-heated steam; also from the oxychloride of copper.

The oxide of manganese and soda process at the present time is more likely to become an industrial process than any other. Until recently we have not had any reliable information as to the cost of production of oxygen in this way. M. Tessié du Motay is, however, prosecuting his experiments with a good deal of perseverance, aided by capital; and I have no doubt of its ultimate success. The only application that has yet been made of it is for illuminating purposes, in conjunction with coal gas, by heating a cylinder of magnesia or zirconia, forming a Drummond light. There have been a good many practical difficulties in the way; some have already been overcome successfully, and the others will be made to succumb to the ingenuity of the age. It has also been applied to bleaching, which process was exhibited by M. Tessié de Motay, and is thus described by the correspondent of the Chemical News.

PROCESS OF DE MOTAY.

The fibers, threads, and tissues contain two sorts of coloring matters—one soluble, after oxidation, in alkaline lixivias; the other substances

inherent to the cellulose, which should be bleached by the oxygen of the air and light, or by chemical compounds able to disengage oxygen in its nascent state.

The methods hitherto employed for bleaching or decolorizing tissues depend upon the alternate application of two sorts of agents :

1. Oxidizing substances; 2. Solvents.

But these methods, perfect as they are in their way, have the following faults: The employment of an oxidizing agent which acts with extreme slowness when it is taken from the atmosphere, or with a destructive combustible power when it is several times placed in a medium containing chlorine or the chlorated compounds, such as the hypochlorites, for example; the use of alkaline solvents, which act with extreme slowness in dissolving the quantity of coloring matter altered by the oxidizing agents. For these latter the most suitable substitutes are: 1. Permanganic acid, produced by the decomposition of the permanganates by means of hydrofluosilicic acid. 2. The alkaline permanganates, with the addition of chlorides, sulphates, and alkaline fluosilicates capable of forming salts, having for base permanganic acid, at the moment when this acid is decomposed by the fibres passing themselves into a basic state, as is shown presently.

In order to employ practically the oxidizing agents and solvents above mentioned, the operation is thus :

"For bleaching stuffs or threads of cotton, linen, or hemp, all the grease or fatty matter is extracted by an alkaline bath. They are then steeped in a solution of permanganic acid or permanganate of soda, with the addition of sulphate of magnesia. Afterwards (15 minutes interval generally) the substances to be bleached are removed and transported either into alkaline solutions or into baths containing sulphurous acid, nitrosulphuric acid, or peroxide of hydrogen. In the first place the substances are heated to the boiling point in alkaline solutions for several hours, until the oxide of magnesia, which covers them, is partially or wholly dissolved. In the second case the substances to be bleached are steeped in baths containing sulphurous acid, or nitrosulphuric acid, or oxygenated water, until the layer or oxide of manganese, with which they are coated, is entirely dissolved; after this they are washed and resteepled, first in a solution of permanganic acid or the permanganate, afterwards in alkaline solutions or in the solvents above mentioned, and so on till the bleaching is completed. A bleaching bath containing, according to the nature of the fibers or tissues to be bleached, from two to six kilograms of permanganate of soda, is sufficient to bleach effectually 100 kilograms of cotton, hemp, or flax, raw or woven."

This method of bleaching is the same for wool and silk, except that the alkaline liquid is a weak solution of soap, and the sulphurous acid is alone employed.

"The industrial results obtained in the factory of M. Verlay, at Comines, by the above-mentioned process, show that hemp and linen

threads are completely bleached, without alteration, in one day; that their tissues are bleached in three days; that the cost for complete bleaching is on an average seven cents the kilogram for threads, and \$1 25 per 100 meters for the woven stuffs.

“By the present methods of bleaching, even the most rapid and economical, all textile substances or tissues threads require, according to the daylight and weather, at least 15 days, and at most 30 days; tissues, from 30 to 60 days. Also the cost of bleaching, on the other hand, amounts in similar cases to about nine cents per kilogram for threads, and \$2 per 100 meters for tissues.”

In order to obtain the practical result which we have just mentioned, new economical processes were necessary to be found:

1. The production of manganate of soda; 2. To transform this manganate into permanganate.

Lastly, we mention that manganate of soda is now prepared and sold at the rate of twenty cents (in France) per kilogram to bleachers.

Its transformation into permanganate is easily and cheaply made, either by means of sulphate of magnesia, chloride of magnesium, or chloride of calcium.

HYDROGEN.

The industrial production of hydrogen gas has also become a matter of considerable interest, and various methods have been devised for making this element cheaply. M. Giffard brings forward a new process, by decomposing water with coke, and converting the oxide of carbon thus formed into carbonic acid by the agency of a second application of steam, increasing the original amount of hydrogen. The water is condensed, and also the carbonic acid, leaving the hydrogen nearly pure. The method is thus described:

GIFFARD'S PROCESS.

“The gas is produced in a sort of furnace charged at the back with coke, divided by refractory stones at the front into a great number of channels, which are traversed by gas. When the fire is well lighted the sides of these channels attain a red heat, and the coke is uniformly red throughout its thickness, which is considerable. Then the damper is shut, the ash-pit closed, and a jet of steam is made to play on the under surface of the coke. By traversing this mass of coke the steam is decomposed, producing carbonic oxide and hydrogen gases.

“At the upper part of the boiler there are nine small jets of steam, which pass through the carbon and mix with the hydrogen and oxide of carbon as far as the red-hot channels, where a new reaction takes place. The carbonic oxide is more highly oxygenated at the expense of the steam, and is converted into carbonic acid gas, while the hydrogen is set at liberty. The system of tubes is very ingeniously contrived; the tube which unites the two boilers and supplies the four cylinders is prolonged

on the opposite side is case of need. Two tubes, which start from the principal trunk, conduct the jets of steam which pass over the coke, and those which traverse it for the production of gas. Two other tubes, called blowers, leading to the ash-pit and the chimney, assist the combustion by jets of steam. The second produces a reversed draught, in order to produce a downward combustion. Lastly, two groups of tubes, furnished with and controlled four ways by cocks, conduct the steam to two cylinders, the object of which is to open and shut, one the ash-pit door, and the other the damper of the chimney. The gas on quitting the generating furnace is necessarily charged with much steam, and it passes into tubes kept constantly surrounded by cold water, changing continuously, which condenses the greater part of the steam; the water of condensation falls into the bottom of a sort of vertical tubular boiler, transformed into a refrigerator, and is let out by a discharge cock. The gas then passes through a lime purifier, in which it is desiccated before it arrives at the bottom. The purifier is a large case of strong boiler plate, with a man-hole at top for introducing the lime, and a grating at the bottom, on which the lime rests and beneath which the gas passes. At a small distance above the grating there are movable plates revolving on their axes. In the ordinary position in which they are placed, vertically on their edges, the gas enters by interstices similar to those of a venetian blind. But when the lower part of the lime is exhausted, the plates are turned horizontally; they then form a floor, on which the unslacked lime rests. The production of gas is intermittent. When the steam has in part extinguished the coke and cooled the sides of the refractory stone, the admission of the steam is cut off, the ash-pit and damper closed, then one or other of the blowers are set in motion, and the operation of gas-making commences."

This has not yet received any application in the arts.

PHOSPHORUS AND ITS COMPOUNDS.

There is nothing new in regard to the industrial production of this element further than this, that the production of the ordinary as well as the amorphous phosphorus is more abundant, and the article is cheaper, than it was five years ago. Its great use is still in the manufacture of friction matches, the consumption of which is enormous.

FRICITION MATCHES.

In France 200,000,000 of matches are used daily, and this represents an annual consumption of more than 12,000,000 of kilograms of wood, or about 50,000 cubic meters. In some countries a proportionally greater quantity of matches is consumed, and the annual consumption of wood in Europe for the purpose is probably more than 500,000 cubic yards of wood.

Austria has the largest factories, some of them employing as many as 5,000 hands. The largest in France is at Marseilles, employing 600

hands; and the entire number of men so employed in Europe is certainly over 50,000, furnishing products having a value of \$50,000,000.

No great progress has been made in the manufacture and safety of this article. A great effort is made to abolish the use of chlorate of potash, and retain the best quality of the match; this is done very successfully by some manufacturers, but others do not pay much regard to it.

With the introduction of this most convenient article into every-day life the number of fires has increased nearly 100 per cent. Accidents through the agency of children have increased as much as 400 per cent., and criminal incendiarism as much as 80 per cent.

In France matches cost the insurance offices about \$600,000 annually.

The phosphorus matches are also dangerous to health and life, and they are not unfrequently used for committing suicide. Those manufacturing them are also exposed to serious injury to the health; good ventilation of the factories can, however, obviate this last objection.

To overcome most all of the objections to this article, amorphous phosphorus, now so well known, should be resorted to. Many manufacturers have used this form, but it has not been much encouraged by consumers, and some manufacturers who employed special surfaces for rubbing their matches on are abandoning it. This is to be regretted, but it should not prevent the industrial chemist from making efforts to overcome the objections.

PHOSPHATES OF POTASH AND SODA.

Specimens of these compounds, made at Javelle, in the establishment of M. Foureade, were on exhibition. The process adopted is a new and cheap one, invented by M. Boblique.

The source of phosphoric acid is in the nodules obtained near Ardennes, and now found so extensively in various parts of the world. The manner of operating is as follows:

To 100 kilograms of the nodules (containing silica 31, lime 28, phosphoric acid 19, phosphorus, &c., 8 per cent.) is added 60 kilograms of an iron ore found near the phosphate deposit, containing about 24 per cent. of water and a silicious and chloritic gangue. The mixture is melted in a blast furnace, resulting in the formation of a phosphuret of iron with 20 per cent. of phosphorus, and a slag containing the other ingredients.

The phosphate of soda is prepared by melting, in an ordinary soda furnace, a mixture of 100 parts of the powdered phosphuret of iron, 200 parts of dried and crushed sulphate of soda, and 30 parts of fine coal. The material is worked and raked during the fusion. When the operation is complete, and the mass is fused, it is run into cakes weighing 1,200 or 1,400 pounds each. Exposed to the air for a few days, it crumbles, and is then subjected to a systematic treatment with water, which dissolves out the tribasic phosphate of soda. This is crystallized and

sent into commerce. The sulphuret of iron and sodium remaining is burnt, and the sulphurous acid is used in the sulphuric acid chamber; the soda is converted into a sulphate, which is washed out from the oxide of iron, and can be used again; so that neither sulphur nor soda is lost in the operation.

BROMINE.

This substance is becoming of more and more importance in the technical arts and in medicine than it formerly was. For many years it was doubtful whether or not its compounds were of any therapeutical value; this is now no longer in doubt; and, while it cannot replace iodine and its compounds, it nevertheless has important uses in the treatment of disease. In the production of some of the so-called coal colors it is already being applied, and its use in this direction will be increased with the diminution of its cost.

The source of bromine is the same as it always has been, viz., the mother water of salines, from which it is easily extracted by heating the mother water to its boiling point, 125° cent., allowing it to flow into a sandstone retort of 200 to 400 gallons capacity, such as is used in making chlorine, having two openings in the cover, one for conducting off the vapor of bromine, and the other, with a tube plunging beneath the liquid, for introducing oxide of manganese and sulphuric acid. The manganese should be soft and of the best quality, and should be boiled in water before being introduced into the retort, so as to expel adhering gaseous matter that is apt to interfere with the regularity of the decomposition. A jet of steam is introduced into the mixture, when bromine is evolved, and is condensed in a proper cooler of glass or earthenware. The operation is continued so long as the vapors of bromine are given off by the addition of oxide of manganese and sulphuric acid, when the still is emptied and fresh materials are introduced. It is more commonly preferred now to add the sulphuric acid to the mother water before introducing it into the still, as sometimes considerable effervescence is produced, and it is an object to prevent this taking place inside the still. The mother water of proper density yields about four pounds of bromine to every 100 gallons of water.

Formerly the great bulk of bromine in commerce came from the manufactory of Schœnbeck, but since the working of the chloride of potassium at Stassfurt very large quantities are produced there, as much as 21,000 pounds per annum, of which the establishment of M. Frank makes about one-half. As in a preceding portion of this report it has been stated that these beds at Stassfurt are almost inexhaustible, with a likelihood of discovering others in other parts of the world, we may expect a gradual diminution in the price of bromine.

Owing to the great risk of sending the liquid bromine into commerce, it is now largely converted into bromide of ethyl, which is readily packed and safely transported. M. Frank converts a large proportion of

the bromine he manufactures into this compound, by mixing bromide of potassium, alcohol, and sulphuric acid, and then distilling. The bromine can be readily reproduced from this compound.

IODINE.

In the manufacture of this substance there are small improvements made from time to time. Messrs. Cournerie formerly conducted all their evaporation over the naked fire; they now carry them on by means of steam, and consider that they have economized the production of this important substance.

M. Moride, who carries on extensive operations on the island of Noir-moutiers, burns a portion only of the sea-weed; the remainder is stretched about the fire and carbonized. This carbon is leached, and the residue is mixed with turf and used as fuel. The inhabitants conduct this operation of carbonization, and sell the material to the manufacturer. In this way 2,000 bushels of this carbon are produced weekly.

The lixiviated solution is concentrated by steam, and the mother water produced, after separating the bulk of the salts, is treated with sulphuric acid strongly nitrous, and the iodine is precipitated. Coal naphtha (boiling at about 120° C.) is now added, and the mixture is agitated, when the naphtha takes up the iodine. This last is now agitated with a solution of soda, and the iodine is separated from the naphtha, which is ready for another operation, as the naphtha does not now contain iodine.

Recently much attention has been drawn to the soda-nitre beds of Peru as a source of iodine, it having been shown, more than ten years ago, that the iodine existing in the mixture was in the form of an iodate. The iodine is obtained by pouring a solution of sulphurous acid or the bisulphite of soda into the mother waters, which precipitates the iodine as a black powder. When the exact proportion of reagents is employed, if there be an excess, the iodide is formed and the iodine is lost; if not enough, the iodate is not decomposed, and is also a loss.

The mining company of Tarapaca produces 200 tons of nitre, and an equal quantity of mother water containing one two-thousandths of iodine. This company, by imperfect treatment, extract only eighty-five pounds of iodine daily. Other works are now looking also to the production of iodine, and when the manipulations are improved a very much larger quantity will be produced; and as these nitre beds will furnish nitre for a great number of years, this source of iodine is important, and deserves careful consideration.

CHAPTER VII.

MANUFACTURE OF ILLUMINATING GAS FROM COAL, AND THE UTILIZATION OF THE WASTE PRODUCTS.

COAL, AND ITS EFFECT UPON THE DEVELOPMENT OF THE ARTS—MANUFACTURE OF GAS; IMPORTANCE AND EFFECTS—MATERIALS USED—RETORTS AND FURNACES—GAS CONDUCTORS AND CONDENSERS—METHOD OF HEATING THE RETORTS—DISTRIBUTING PIPES—EXHAUSTERS—GAS METERS—GAS BURNERS—COLLATERAL USES OF GAS—PORTABLE GAS WORKS—NEW FORMS OF ILLUMINATING GAS—THE CHEMISTRY OF GAS-MAKING—THE GAS WORKS OF PARIS—UTILIZATION OF THE WASTE PRODUCTS OF THE MANUFACTURE OF COAL GAS—COKE—AMMONIACAL LIQUORS—COAL TAR, ITS COMPOUNDS—SPENT OXIDE OF IRON—REFUSE LIME—ABSORBENTS OF AMMONIA—COAL TAR COLORS—VIOLET COLORS—ANILINE REDS, BLUES, GREENS, AND OTHER COLORS—THEORY OF THE FORMATION OF COLORS—CARBOLIC ACID COLORS—NAPHTHALINE COLORS.

INTRODUCTION.

There is not any substance which, in the last forty or fifty years, has produced such wonderful results in the development of the arts, commerce, and industrial pursuits, as coal. It is not, however, our province here to refer to its applications in metallurgy and the other arts in which direct operation brings about the required results; but to confine this and the following chapter to the industrial products obtained from coal by operations more or less indirect.

I had drawn up a report based on the results as exhibited in Paris in 1867, but it was so extended and hastily digested that it has been discarded, and in its stead I have combined my report on gas and gas materials, as made out for the jury reports published by the Imperial Commission, with the admirable lectures of Dr. Letheby on the articles made from coal, and have appended an extract from the report of Dr. Hofmann.

GAS AND GAS MATERIAL.

PROGRESS OF THE ART OF GAS-MAKING.

Important progress has been realized in the manufacture of gas—more, however, in reference to giving stability, and to perfecting apparatus already employed, than in the discovery or application of anything new. The importance of this industry is manifesting itself every day, not so much in the direct products for illuminating purposes, already so well established, but from the great number of valuable and beautiful products resulting from the treatment of the residues by the chemist.

We have become so accustomed to the use and production of illuminating gas from coal that, like most things we are habituated to, the

great value of the product and the importance of the industry, as well as everything else connected with it, is lost sight of alongside of more glaring and recent discoveries of far less magnitude; yet if we review the origin and development of this industry, and the direct and indirect effects of it upon the advancement of the age, it is certainly to be ranked as one of the most important inventions of the present century, and second only to that of the steam-engine.

Its direct effect is to convert night into day, to make the short and obscure winter days equal to those of summer, giving more time to those occupied with in-door pursuits, and enabling them to conduct their labors with less fatigue to the eye and with more certainty of execution. In this aspect alone the immense wealth that has been added to the industrial arts is incalculable.

In its indirect effects, the use of coal gas has benefited society by saving vast tracts of land for other agricultural purposes that would have to be devoted to the cultivation of plants furnishing oil and fatty matters to be used for illumination; and besides, there have been saved for other purposes hundreds of ships and thousands of seamen that would be required for the whale and other fisheries carried on simply for the purpose of procuring oily matter to be used for furnishing light.

Regarded as a luxury, its benefits are not to be despised, for it has cheapened many of them to such a degree that both rich and poor are equal participants of them. Our brilliantly lighted streets are evidence of this fact, so that the people traverse our cities with the same ease and security at night as in daytime. And here we may again allude to another fact in connection with the manufacture of coal gas, namely, that the offensive residues which are the natural result of gas making have been made to give rise to most important industrial pursuits, employing a large amount of capital and accumulating wealth. Coke, ammonia, pitch, and tar have been for many years drawn from this source; but it has been left for the more recent developments of chemistry to extract from the tar, by processes more or less indirect, beautiful crystallized compounds used in giving to silk, woolen and cotton, colors that rival in brilliancy the hues of the rainbow; and this discovery in its turn reacts on the manufactures of the various textile fabrics. All of these facts will be most fully developed in the report on coal colors, by Professor Hofmann, to whom we are indebted for the first and most important steps in their manufacture.

It is not the design or province of this report to go into the historical details of the origin and development of this industry. Like many other great discoveries, the world was prepared and looking for it. The minds of many were occupied with it, and the distinguished Scotch philosopher, Dr. Chalmers, "at a time when the streets and lanes of all great cities were lighted with oil burnt in lamps, held that the time was not distant when a carburetted-hydrogen gas would be substituted instead, and on getting his house repaired he actually introduced into the walls of the

house a system of tubes and pipes for the passage into the various rooms of the gaseous fluid yet to be employed as the illuminating agent." But among all the vague speculations and ingenious devices, there were two individuals endowed with skill and practical minds, who were giving shape and form to them—Murdock in England, and Le Bon in France. The combination, however, of circumstances favored the former, and I think no impartial investigator of the subject will fail to render to William Murdock, of Redruth, Cornwall, the sole merit of the practical application of coal gas to the purpose of artificial illumination, in about 1800. And it is a noteworthy fact that this discovery was first exhibited publicly as a rejoicing over the hush of war and the renewal of peace, on the occasion of the grand illumination in England commemorative of the peace of Amiens, in 1802.

Since the commencement of the century to the present time the industry of coal gas has been gradually improved, and the mixed nature of this compound has been more and more simplified, rendering the illuminating gas better adapted for the purposes to which it is applied; the condensable products and impurities are better removed, and the latter, in their turn, made to subserve some useful purpose, until the gas manufacturer receives the coal from the mines and sends forth nothing that is useless.

In a systematic review of the gas industry and products resulting therefrom, so far as regards its more recent improvements exemplified by the great Exposition of 1867, the remarks will be confined especially to what was there exhibited.

MATERIALS USED FOR MAKING ILLUMINATING GAS.

The Exhibition does not furnish anything new under this head. To sum up what is now known can be done in a few words.

The materials now used in the manufacture of gas may be comprised under the following articles: coal, wood, pitch, rosin, oils, fats, and petroleum. There are also other vegetable and animal products which have been suggested, and even employed, on a small scale, as bones, &c. But of all the raw materials there are none which can compete with coal, except under some extraordinary combination of circumstances; for not only does coal furnish gas more economically, but it affords valuable residues, producing the fuel necessary for its formation in much larger quantity than is required for that purpose, and other important refuse matter, as tar, ammonia, &c. The question in regard to the substitution of petroleum for coal is not worth serious consideration at the present time. It may be advantageous occasionally to add, in a convenient manner, some petroleum when this is abundant and the coal used requires the addition of a material to furnish gas of a high illuminating power; then from twenty to thirty gallons of petroleum to 2,000 pounds of coal may become desirable. Pitch and rosin, when cheap, may be added to coal for the same purpose. All other adjuncts, as vapor of water, &c., serve

only to dilute the gas and make it of less value. Bituminous coal, under its various forms, has not found a rival, nor is it likely to encounter any for a long time.

The following fact may be mentioned in connection with the manufacture of gas from wood. In those countries where this material is abundant and coal is not accessible, wood, aided by the addition of some substance furnishing a rich hydro-carbon, may be made to furnish a very useful illuminating gas, and an economical one, especially when the residue in the retorts and the material distilled with the gas can be rendered serviceable. In Coburg, Canada, it is said to have been used advantageously, furnishing a good gas and a valuable residue, viz.:

Two parts pine wood.

One part hard wood.

One part bones.

The residue in the retorts is an excellent charcoal for bleaching purposes, and the other residues are quite serviceable. Where bones cannot be obtained, offal and other coarse animal matter can be used to mix with the wood. This suggestion is worthy of consideration, especially for many small towns peculiarly situated.

RETORTS AND FURNACES.

These are the first and most essential parts connected with gas-making; and the present Exposition is rich in specimens of these from various countries. In the Belgian department, we have the fire-brick, tiles, and retorts from "La Société anonyme des terres plastiques et produits refractaires d'Andennes," a company employing nearly 20,000 tons of clay annually, requiring about two hundred and twenty men, and having thirty-two large kilns. Among the articles exhibited by this company are very large retorts, one of which is over ten feet in length and two feet across, with an opening of about seventeen inches, and two inches thick; it weighs about 1,700 pounds, and is of most excellent manufacture, which is equally true of all other articles exposed by the company. Near the above are to be found the retorts of Sugg & Co., of Ghent, who supply, to a very large extent, the gas works of Germany. From Prussia there are excellent products of fire clay, made by Vygen & Co., of Duisburg, and used in Germany, Holland, and Switzerland. England is represented by the well-known products of Cliff & Son.

France furnishes retorts and gas ovens of excellent quality; there are several exhibitors, but none are so conspicuous as those from Bosquet & Co., Lyons, and from the Paris gas company. The retorts from the former establishment are covered with a kind of black enamel, and are set in the gas ovens by being simply supported at the two ends. Without further investigation, I should doubt the advantage of this style of setting; its simplicity may be too great a sacrifice to its security.

The black enamel here referred to is composed of—

Galena.....	54
Silicious sand.....	24
Oxide manganese.....	15
Iron scales.....	7

It is said that this is put on to render the retorts less sensible to variations of temperature.

There is, however, no establishment so thoroughly organized or confining itself strictly to the refractory materials necessary for gas ovens as the Paris gas company, about which it may be well to make a few detailed statements, as the plan of operation of this company may be advantageously followed by other large gas companies. The works of this company are at La Vilette, a place most conveniently located for the purpose, as railroad and canal communications bring all the necessary materials to this point, and it is on the same premises as the extensive gas works of that locality. It has been established since the consolidation of all the gas works of Paris, about twelve years ago, and it furnishes retorts and other refractory materials required by the different works in Paris and in many other parts of France. The mills, mixers, &c., are set in motion by a forty horse-power engine; but all the manipulations, after tempering the clay, are performed by the hand, requiring about forty men for the purpose, as no machinery has yet been devised to replace successfully the use of the hand in giving the necessary uniformity of consolidation to the plastic material employed in making the retorts and the large tiles, that are constructed by compacting together the materials in small lumps, using for that purpose the blows of an iron hammer or wooden mallet.

The articles manufactured at the Paris gas works annually are:

Retorts.....	3,000
Blocks and tiles.....	20,000
Bricks.....	1,000,000

All the burning of the above is accomplished in furnaces heated by coke.

It is an interesting fact connected with this establishment that there is no refuse rejected; for even the ash of the furnace is used to make a tile for the floors of its own work-rooms, and their excess is sold outside for similar purposes, for stables, &c. The ashes are mixed with a common clay, the cinders being pulverized; the mass thus formed is very dense, and is slightly vitrified. It is said to replace very advantageously the pavements of workshops, now commonly made in brick—about fifty per cent. of ashes being used.

Among the articles exhibited by this company are large pieces of refractory materials—one of a perfect tube ten feet long and forty-three inches in diameter, and one solid mass of eighteen tons for the floor of an oven. There is a small model of their gas-oven complete, with retorts, &c.

In the above statement in regard to gas retorts there is nothing new that has been developed in the past five years. It simply shows that the old iron retort, originally used, is more and more thoroughly excluded than ever from gas works; for, while a clay retort may require a little more fuel than an iron retort, this is more than compensated for by its original cost and durability, and the possibility of using a higher temperature, one better adapted to the generation of gas, viz., $1,200^{\circ}$, which cannot be employed with an iron retort.

As regards the manner of setting the retorts in the ovens different plans are proposed by different engineers, each having their advocates. In London, gas ovens are often made with ten retorts eighteen feet long and open at both ends, each retort being composed of three pieces. In Paris, the retorts are of a single piece about nine feet long and open at one end, and in each oven there are six or seven retorts. We understand that in London there is a tendency to give up the ten-retort system, and not to exceed six or eight to an oven; regularity of temperature and facility of emptying the retorts would recommend the latter.

The system of through settings with double mouth pieces is very much objected to by some gas engineers. Henry Gore, in a paper read before the British society of engineers, says: "In large works, and with clay retorts, the system of through setting, with double mouth-pieces, is unquestionably the most economical, both as regards fuel and durability. But this arrangement is open to grave objections. If the retorts are used for the generation of gas of high illuminating power, the increased surface over which the gas passes after it is eliminated from the coal exposes it to the chance of decomposition, and the consequent deposition of its carbon. That this goes on to a very great extent is evident from the amount of solid carbon, or graphite, found on the inner surface of the retorts. In through retorts this deposition is due mainly to two causes: in the first place, in charging the retort with coals either by the scoop or shovel the center of the retort scarcely ever receives its due portion of coal, and as this part is always the hottest, it follows that the gas generated from the thinner stratum of coal is exposed to intense heat, and a portion of it is decomposed, liberating the hydrogen and depositing the carbon, thus forming a deposit which rapidly increases and soon renders the retort useless, unless precautions are taken from time to time to remove the carbon. Another cause of this deposit is the want of uniformity in the pressure in the two hydraulic mains; a slight resistance in one main or the other causes the gas to take the course offering least obstruction, and as the particles of gas thus pass over a large amount of heated surface, they are exposed to the greater risk of decomposition. Several expedients are suggested to remedy this evil; one is to use a valve to each ascension-pipe, so as to dispense with the dip-pipe when the retort is working; another is, to have only one hydraulic main, placed over the center of the ovens, and both mouth-pieces connected to it by a single dip-pipe."

CONDUCTORS OF GAS FROM THE RETORTS, CONDENSERS, ETC.

Under this head we obtain no new suggestions in the present exhibition. In the gas works visited all the conductors of the older parts have been too small, their dimensions being based on calculations made in reference to gas unmixed with thick, condensable vapors in suspension. This is, however, avoided in all new constructions. In some works, instead of a hydraulic main to every row of benches, only one is used for those ovens worked back to back, this being placed in the center line, the hydraulic main being constructed of sheet-iron three-eighths of an inch thick, to avoid risk of breakage from irregular settling and expansion. All these points are worthy of consideration. In condensers there has not been any striking or useful novelty in recent years, and nothing at the exhibition suggests any.

METHOD OF HEATING THE RETORTS.

All that is novel under this head is the application of Siemens's gas oven and regenerative furnace to this purpose. There is a model of this furnace in the Exposition, and, as its application is of a general character and is already well known, I leave to other reporters all that is to be said concerning it. As regards its applicability in heating gas retorts, this has been successfully carried out at the Vaugirard gas works, at Paris, and the gas works in Birmingham, England.

The experiments made at Vaugirard were with a single generator applied to heat sixteen ovens of eight retorts each, and there has been found a saving of from twenty-two to twenty-nine per cent. of fuel, and the results have been sufficiently satisfactory to encourage the Paris gas company to adapt it to other works when needed to be refitted.

PIPES FOR DISTRIBUTING GAS.

In several of the classes there are exhibited pipes for this purpose. There are cast and wrought iron pipes, bitumenized paper pipes, bitumenized sheet-iron pipes, copper, lead, brass, vulcanized caoutchouc, and a new material, called parkesine, in the English department. As most of these pipes will be reported on by others, only a few remarks will be made with special reference to their use in gas distribution. Cast-iron pipe is still used in most countries for the distribution of gas through cities. In France, however, they have been more or less abandoned, although it is a question if this can be done advantageously.

The exhibition of cast-iron pipes from the various countries is certainly magnificent, but the beauty of the French castings is not excelled and is rarely equalled. There are some new plans proposed for joining the pipes—one by M. Marini called the universal joint, made with rings of caoutchouc and cast-iron bands; but it is doubtful if any joint made with caoutchouc is to be relied on for any length of time, where gas is to be conducted, and where naphtha and other condensable products will be constantly acting on the joint.

WROUGHT-IRON PIPE.

The specimens of these pipes on exhibition merit a special notice by the proper reporter on the subject. Those intended for conducting gas have no special merit beyond those of former Expositions. The use of these pipes in conducting gases through houses is very limited in France compared with their similar use in England, America, and other parts of the world; lead and composition pipes supplying their place. Other purely metallic pipes used in conducting gas present nothing novel. The specimens of lead pipes show to what great perfection their manufacture has been developed, and there seems to be no limit to the length which can be given to a single pipe. One specimen on exhibition is 8,000 feet long.

Caoutchouc pipes show no improvement in quality of composition. They are all permeable to gas, which defect can, however, be more or less perfectly remedied by two or three coatings of boiled linseed oil applied to the external service, a precaution that will render the use of this conductor, especially in chemical laboratories, far less offensive. Parkesine is an artificial composition for gas pipe, and it is said can be substituted advantageously for caoutchouc. It is to be found in Class 44 of the English department, and is said to be made of gum-cotton and other chemical compounds. Bituminous pipe is on exhibition, and is recommended for conducting gas. It is stated that it is used in some places for this purpose; but the well-known action of certain of the constituents of gas on bitumen would naturally militate against its use.

BITUMENIZED IRON PIPE.

Under this head there are gas pipes exhibited by Messrs. Chameroy & Co., of Paris. While these pipes are no recent novelty, yet they deserve especial notice, as the manufacture of them has received during the past few years a wonderful extension, for the purpose of conducting water as well as gas. The base of the pipe is sheet-iron, leaded, varying in thickness according to the required size and pressure; each section of pipe is made of two sheets, that are first riveted together separately with tinned rivets, and plunged into a bath of melted lead; these two pieces of pipe are then riveted together, and the junction of the two well tinned. The entire pipe is now thirteen feet long. On the ends are cast convenient sockets and spigots, made of a mixture of lead and antimony, and these serve to unite the sections of pipe when laid in the ground. The exterior surface of the pipe is coated with tar, and around this is wrapped a cord; this cord is then covered with melted pitch, and the pipe then rolled in coarse sand until it has acquired a thickness of from one-fourth to five-eighths of an inch.

In attaching a service pipe to these pipes when used as main pipes, it must be done by soldering a lead or composition service pipe to the main, in order to make a good and effective junction.

It is impossible for the reporter on this article to form a correct opinion upon the merits of this pipe as a conductor for gas. In lieu of this, a statement will be made of the statistics of the products of the works of Messrs. Chameroy & Co. In one year was made one hundred and fifty-five miles of pipe, for gas, from one and three-quarters to twenty-eight inches diameter; the Paris gas company have in ten years laid four hundred and thirty-six miles of these pipes. In the exhibition building there is nearly one mile from twelve to twenty-four inches diameter, and since the foundation of the establishment in 1838 the products of the works have been as follows:

	Miles.
France, for gas.....	2,577
France, for water.....	664
In other countries, for gas.....	583
In other countries, for water.....	233

Entire value of the above, \$7,708,400.

There is an objection in using this pipe, arising from accidents to it that may happen when excavating near them, as the point of a pick can be driven into them without producing disturbance enough to make the accident evident at once, but which may subsequently give indications by leakage, causing serious accidents; one of which occurred recently in France.

EXHAUSTERS.

For many years the adoption of exhausters has been considered a matter of economy in all large gas works; but more especially, since the introduction of clay retorts, they have become an absolute necessity. There is nothing new exhibited in the way of improvement in gas exhausters, and the opinions of engineers are still divided between the use of exhausting cylinders and rotary exhausters. Schiele, of Frankfort, exhibited a rotary exhauster, said to work well, and very economical in its original cost. In Paris, an exhauster with three cylinders, devised by M. Arson, is employed in the gas works. One of these exhausters has been for eight years in continual use. Brochi exhibited one consisting of three small gas-holders, with their bottoms plunged in tar, and worked alternately by one of Hugon's gas engines.

GAS METERS.

We find on exhibition both wet and dry meters. The wet meter is the one most commonly in use on the European continent. In France there are but few dry meters employed, and consequently there has been a good deal of attention given to the improvement of the wet meter.

One of the modifications of this meter, as made by the celebrated manufacturers MM. Brunt & Co., is that the "syphon and regulator are bent in a vessel having a vertical tube which enters the waste-water box. The tube is separated by a diaphragm from the inside of that box, on

which the spindle of the drum turns; the meter thus fulfills the following conditions prescribed by the administration of gas in Paris and other parts of France:

"The examiner, having left all the orifices of the meter open, shall ascertain that the float, the siphon, the hydraulic seal of the vertical shaft, and the inlet pipe for the water, are water-tight under a pressure of at least four inches."

Other French exhibitors, as Messrs. Siry, Lizars & Co., and M. J. Williams, show most perfect workmanship in their apparatus, the latter manufacturer paying a great deal of attention to testing apparatus. Almost every European nation is represented by gas meters; and England, the greatest of all gas-consuming countries, is, as might be expected, fully represented with everything in the way of meters, both wet and dry, which are active competitors for the ascendancy in England. The dry meters of MM. George Glover & Co. are as complete as they can be made with our present knowledge, and are world-renowned for their accuracy and durability. The wet meters of the Globe Meter Company are well arranged for adjustment of water level, and are said to require adjustment but once a year. There are other makers who arrive at the same end by different means.

The compensating meter of Messrs. Sanders & Donavan, of Dublin, accomplishes this by an independent compensation float, not interfering with the machinery of the apparatus. In the articles exhibited by the gas meter companies of London, Oldham, and Dublin, there is a pressure generating meter, in which a spring or weight, as in a clock movement, is made to increase the pressure, a desideratum in some instances where the street pressure is not sufficient. The first meter to which is attached the movement draws in gas say into a ten-light meter; from this it passes to a ten-light dry meter, and then through a five-light wet meter of variable level.

Many of the English meters are now made with cast-iron outer casing instead of tin plate. There are various large station meters exhibited, that have all possible care bestowed on their construction; but there is no novel feature in any of them worthy of special mention.

GAS-BURNERS.

As the chief use of coal gas is to be burnt for the purpose of affording light or heat, it is only second in importance to the economical production of gas to obtain the greatest amount of light from a given quantity of gas; yet while there is continual attention given to this subject, but little advancement has been made during the last few years. This arises from the fact that the circumstances under which gas is burnt are so variable that no one rule is applicable in all cases. The unavoidable variation of pressure at the works and in the main are irregular, variable quantities; so are the differences arising in different stories of the same building, and other well known causes.

The only principle by which it is to be expected that a burner will regulate itself to the differences of pressure is by the use of a movable diaphragm and conical valve like that used on the governor at the gas-works. Messrs. Suggs, of London, and others in different countries and at different times, have adopted this principle, and Suggs's regulators may be seen attached to many of the street lights in London. They are still far from being perfect, and this arises from the necessarily diminutive nature of the regulating adjustment.

There are some regulators which can very advantageously be attached to the gas pipe as it enters the building prior to its distribution. The one on exhibition by M. Henri Giroud deserves special consideration, while at the same time it is far from filling all requirements; but, with the occasional superintendence of some one attending specially to the business, much gas might be saved to the consumer. The same inventor exhibits what he calls a *telegraphic regulator*, upon the same principle as the smaller regulator, but which can be attached to the main pipes in any part of their distribution; and, by a system of return pipes, electrical and clock movements, these irregularities are made sensible to the governor at the gas works, which opens or closes the valve of the main regulator and establishes the proper equilibrium between the pressure at the works and that in the main pipes. A thorough explanation of this apparatus would require several drawings and more detail than can be given in a report like this. It has been in practical use in several places, and is well spoken of.

But, after all, an attention to the cocks once or twice in the evening is the simplest and most economical way for private consumers to regulate their consumption of gas. This, however, cannot be applied very conveniently in the public lights; so there is much yet to be done in furnishing a proper regulator to be applied to each lamp, either just under the burner or at the base of the lamp.

The form of the jet through which the gas issues prior to being ignited is of the utmost importance to produce the best effect. Those now in general use are three: the *bat-wing*, a burner with slit; the *fish-tail*, or Manchester burner, with two oblique openings in the end; and the *argand*, a circular burner with a number of small holes. The only investigations upon the best form for burners, the results of which are to be found in the Exposition, are those of MM. Audouin and Berard, (the former connected with the Paris gas works,) and have been conducted with the utmost skill and ability.

It is of importance to furnish in some little detail the results of these experiments as they bear particularly on public lights; no reference will be made to the preliminary experiments bearing upon the method of experimenting, or the photometric arrangement. The carcel lamp, burning forty-two grams of oil per hour, is the term of comparison; as the agreement between the city of Paris and the gas company is that from twenty-five to twenty-seven and a half litres of gas, under a pressure

of from two to three millimeters of water, must furnish a light equal to that of a candle lamp burning in the same time ten grams of purified colza oil.

The first set of experiments was made with the *bat-wing* burner, with a round extremity connected with the main part of the burner by a short, broad neck. A variety of these burners was made. They varied in the diameter of the button and the width of the slit, and the experiments with them gave the following results:

1st. That the maximum effect of illumination corresponds to a slit of seven-tenths of a millimeter.

2d. In comparing a tip having one-tenth of a millimeter with one having seven-tenths with the same quantity of gas, the latter gave an illuminating effect more than four times as great as the former; consequently, the same quantity of gas can give, when it burns in a good tip, four times more light than when burnt in a bad one.

3d. That the intensity increases more rapidly than the increase in the width of the slit.

4th. That the augmentation of illuminating power corresponds to a very rapid diminution in the pressure, and consequently to a diminution of the flow of gas during the combustion; and that for each series of burners experimented with, the maximum corresponds to a flow measured by a pressure of two to three millimeters.

The experiments in relation to the dimensions of the buttons at the end of the burners showed that as the dimensions of the buttons became greater the flame became less steady and had a tendency to smoke. That for every given consumption of gas there was a button of a given diameter, that produced the best effect, using a slit of seven-tenths of a millimeter, which, as has already been observed, gives the most advantageous results; the diameter of the button employed in Paris for the slit above mentioned, which is the one now used, is seven millimeters.

Although the results of the experiments have led to the use of the *bat-wing* burner in public lights, it is as well to state the results of MM. Audouin and Berard in relation to other burners. As to the *fish-tail*, or Manchester burner, it was shown that it should be burnt with a pressure of at least three millimeters; if this were not the case, the two jets of gas would not encounter each other with sufficient force to spread the flame. The diameter of the holes for the maximum of illuminating effect is comprised between one and seven-tenths to two millimeters, but it is necessary for holes of this size to consume about two hundred litres of gas. For the consumption of one hundred to one hundred and fifty litres of gas per hour the diameter of the holes should be about one and a half millimeters. The *Argand burner*, which consists of a circular ring pierced with small holes, is much in use for private illumination, especially in Paris, and the study of this burner was a matter of considerable interest, and the result of the experiment was that the differences of intensity were due, 1st, to the diameter of the holes; 2d, to the number

of holes; 3d, to the distribution of the air; 4th, to the height of the glass chimney. As regards the size of the holes, a diameter of seven-tenths of a millimeter is considered the most advantageous; as to the number of the holes, a large number was considered advantageous—thirty being a convenient number, a feeble pressure giving the best effect for the same amount of gas. A cone to concentrate the air on the flame is useful, and the best height for the glass chimney was twenty centimeters. The advantages in illuminating effect increase indefinitely with the amount of gas consumed, and can be carried even to the point at which the flame passes the glass, when of course further increase becomes impracticable. All of these statements in reference to this burner have reference to its equaling the illuminating effect of a carcel lamp burning forty-two grams of oil an hour.

The same experimenters have shown that when it is required to illuminate a large space it is best to increase the size of the burner, as by that means the maximum effect is obtained from a given quantity of gas; and the city of Paris has adopted one giving the effect of three and one-half carcel lamps with a consumption of only three hundred and sixty litres of gas. It is a *bat-wing* burner, with the diameter of the button of fifteen millimeters and a slit of six-tenths of a millimeter.

MATERIAL FOR TIPS OF BURNERS.—These are made either of metal or earthen material. Of the metals, iron, brass, and various compositions are used. The earthy materials are lava, porcelain, soapstone, and artificial compounds resembling these. There is nothing new under this head, except that great progress has been made in the manufacture of burners of every form and description from these earthen materials, and they are likely to replace to a considerable extent those of metal, as the small openings are not as liable to be stopped up by the action of the air as the metallic ones are.

COLLATERAL USES OF GAS.

In various departments of the Exhibition are to be seen a variety of uses to which gas is applied besides that of illumination. Lenoir, Hu-gon, Otto & Langen have developed its use as a motive power by igniting a mixture of air and gas in cylinders. For domestic uses, as that of cooking, it has received a very extensive application, and can be employed economically under a variety of circumstances. Stoves, large and small, of various devices, are to be found, especially in the English and French departments. It is also used largely by the workers in metals, for the purpose of soldering, and various other manufactures where a conveniently regulated and an intermittent source of heat is required. The chemist in the laboratory for analysis and research uses gas to the exclusion of almost all other sources of heat, and a great variety of convenient and ingenious arrangements for their use are to be found in the German, French, and English departments. There is,

however, no really novel form of apparatus on exhibition. Some remarks on its application as a motive power will be found in another report.

POR TABLE GAS WORKS.

There are several on exhibition, but they represent nothing of noteworthy novelty. MM. L. Coignard & Co. exhibit small gas works, on the plan of M. G. Jonanne, for the purpose of using all substances capable of furnishing illuminating gas. In the English department there are several compact and economical gas works from two or three makers. Mr. George Bower makes gas works furnishing six to eight lights for four hours at the price of \$110.

NEW FORMS OF ILLUMINATING GAS.

For many years various efforts have been made to impregnate air with the vapor of the light hydro-carbons, and igniting the vapor thus suspended as it passes through burners similar to those used for ordinary gas. Under some circumstances very good effects are produced. But variations of temperature interfere with the regularity of the light, and in places where public gas works exist they cannot be brought into use, even if it should be shown that the consumption of material to produce a given illuminating effect is less expensive than the cost of the public gas, for certain manipulations are necessary which are incompatible with the nature of service to be found in private houses.

THE CHEMISTRY OF GAS-MAKING.

The progress made in the knowledge of the chemistry of gas-making deserves special consideration, not only in regard to the manufacture and purification of the gas, but the utilizing of the waste products. Under this head I will merely make a statement in regard to the operations of the Paris gas works, and in doing so there is no injustice done to other gas works, for none of them work up so thoroughly the waste products.

GAS WORKS IN PARIS.

In 1856 all the gas works in Paris were amalgamated into one, conducted by a private company, which supplies Paris and all its suburbs for six or seven miles outside of the fortifications of the city, which last have a circumference of about twenty miles. In 1856 the annual consumption of gas was 1,671,746,970 cubic feet. In 1866 it had increased to 4,320,491,244 cubic feet, and the capacity of the works is sufficiently great to supply five billions of cubic feet of gas per annum. There are 71,836 private consumers, and 32,232 public lights. To produce the amount of gas required, the works used, in 1866, 421,000 tons of coal.

"The coke produced in 1866 by the Paris gas company amounted to 613,626 chaldrons, part of which was consumed in the gas works, and the remainder sold to the public. To facilitate the sale of the coke, the

company manufactures stoves specially adapted to heating by this means, and sell them to the public at a very moderate price. The heating by coke offers so many advantages, that from the 1st of January, 1858, to the 28th of February, 1867, the Paris company sold to private individuals alone 16,909 of these stoves. The quantity of tar produced from the distillation of coal amounted last year to 21,540 tons. To facilitate the disposal of this product the company are obliged to distil a large portion of it. Of the 21,540 tons produced in 1856, they distilled 20,074 tons, which yielded 13,600 tons of pitch, at the price of from \$1 50 to \$2 per 220 pounds, the substance being used in the manufacture of patent fuel and artificial asphalts. They obtained, besides, 524 tons of light oils, and 3,660 tons of heavy oils. The former have been sold as benzine for scouring clothes, for painting, and in caoutchouc manufactures, or they have been converted into nitro-benzine or aniline. The production of nitro-benzine amounted to 133 tons, and that of aniline to 1,327 pounds. With regard to the heavy oil, (creosote,) it has been sold to the dealers in wood, and has been almost entirely employed in the impregnation of railroad sleepers. A certain quantity of this heavy oil has been purified and used as a lubricator and in common painting. The tar oils always yield an appreciable quantity of phenic acid, which, in a liquid state, is of use for disinfection, and when crystallized, for the making of picric acid; and it is used in medicine. The purification of gas supplied last year about 3,000 tons of ammoniacal products, either in the form of sulphate of ammonia or volatile alkali. A certain quantity of sulpho-cyanide of ammonia has also been obtained from the products of the condensation of gas. The waste materials used in the purification of gas have been purchased by the manufacturers of Prussian blue; but as the residuals contain not only sulpho-cyanides and cyanogens, but also a considerable quantity of sulphur in a free state, the company have treated a part of them by a special process, and have obtained a material which contains from fifty-five to sixty per cent. of free sulphur, which may be employed in manufactures or in agriculture. It will be seen from these results that the company have turned to good account the residual products of the distillation of coal."

The gas of these works is most thoroughly purified, and the dealers in silks and other delicate fabrics, who, a few years ago, always suffered more or less loss from the results of the combustion of the impure gas acting on their fabrics, now no longer suffer from that cause. The purification of their gas, as that of a great many of the large establishments in Europe, is effected by the oxide of iron, which, although a little more costly than lime, has the advantage of being readily restored for repeated uses, and avoids the accumulation of that most disagreeable of residues—gas-lime. My observation, however, leads me to believe that the purification by oxide of iron had better be aided by the wet lime process. Much more might be said on the present condition and requirements of gas-making, but to do so would exceed the expected limits of this report.

UTILIZATION OF THE WASTE PRODUCTS OF THE MANUFACTURE OF COAL GAS.¹

The residual products of gas-making are six in number—namely, coke, ammoniacal liquor, coal tar, and the three waste products from the purifiers, as the spent oxide of iron, the refuse lime, and the acid or other matters used for absorbing ammonia, each of which has its special value on account of its technical uses.

I.—COKE.

This need not occupy much of our attention, as its practical value and uses are pretty well known to you. I may say, however, that it was the opinion of the late Dr. Fyfe, and is still the opinion of many chemists who have examined the power of coal under steam-boilers, that the heat actually made available in practice is very nearly the same as ought to be produced according to theory by the quantity of coke which the coal yields. He found that a pound of Scotch coal from Trenant would boil away 5.61 pounds of water, and that the coke of it, which amounted to 0.525 of a pound, produced 3.9 pounds of steam; so that the practical loss was $5.61 - 3.9 = 1.71$ pounds; but the theoretical value of the coke was about 5.5 pounds of steam. Here is a table of the relative heating power of different fuels, expressed in the number of pounds of water which one pound of the substance will boil away when the water has been heated to its boiling point:

	Pounds.
Dry wood (average of many specimens)	4.51
Derbyshire coal (ditto)	7.58
Scotch coal (ditto)	7.70
Lancashire coal (ditto)	7.94
Newcastle coal (ditto)	8.37
Welsh coal (ditto)	9.05
Good coke (ditto)	10.00

If all these numbers are multiplied by 5.5, they will give the quantity of water which a pound of the fuel will in each case raise from 32° to 212°, and the results show that the thermotic power of coke is very high.

II.—AMMONIACAL LIQUOR.

This is the aqueous portion of the condensed products of the gas. It floats upon the tar, and is a watery solution of carbonate, sulphide, and sulphocyanide of ammonium, with certain carbohydrogens of no value.

If all the nitrogen contained in coal were converted into ammonia, so as to make a liquor of eight ounces strength (4° Twaddle,) it would yield from 142 to 226 gallons per ton of coal. This will be evident from

¹ From a lecture delivered before the British Association of Gas Managers, by Dr. Letheby, and communicated by the author to the *Chemical News*.

the table which is before you, and which represents the average amounts of nitrogen in certain well-known coals in a dry condition:

Varieties of coal.	Nitrogen per cent. in coal.	Ammonia per cent. from coal.	Gallons of liquor of 4° Twaddle per ton of coal.
Welsh coal, (average).....	0.91	1.10	142
Lancashire coal, (average).....	1.25	1.52	196
Newcastle coal, (average).....	1.32	1.60	206
Scotch coal, (average).....	1.44	1.75	226

But by far the largest portion of nitrogen is not converted into ammonia, for by combining with sulphur and carbon it forms the sulphocyanides which are so abundant in ammoniacal liquor and in spent lime, and much of it also unites with carbon and hydrogen to produce the alkaloids which exist in the tar. In practice, therefore, you get but a comparatively small proportion of the nitrogen as ammonia in the ammoniacal liquor. The quantity of liquor rarely exceeds forty-five gallons of eight-ounce strength per ton of coals; and to obtain this quantity you must condense well, and also wash the gas with water. I have already explained to you how this is done at the Birmingham and Staffordshire gas works, by Mr. Hugh Young, who obtains forty-four gallons of liquor per ton of Staveley coal in his yearly working. In ordinary practice the yield is about twenty-five gallons per ton, and in London it is not above thirteen gallons—calculated in every case as eight-ounce liquor. You will see from this how largely the production of ammoniacal liquor may be increased; and I will call to your recollection the valuable advice of your president, Mr. Hawksley, with respect to the copious washing of raw gas with ammoniacal liquor, for this practice has a twofold advantage—it not only purifies the gas by removing tarry matter and sulphur compounds, but it also strengthens the liquor and renders it a more valuable product. By using the liquor as a shower or in a scrubber, in the proportion of one volume of liquor to sixteen of gas, the liquor may easily be raised to 10° or 11° of Twaddle, which are equivalent to from twenty to twenty-two ounces of acid; and considering that the price of liquor rises about 4d. or 6d. per butt for every degree of Twaddle, it is manifestly of the greatest importance that the liquor should be sent away from the works as strong as possible. It ought, in fact, never to be under 6° of Twaddle, or of less than twelve ounces strength; and, with proper condensation and judicious washing, there should be from twenty-nine to thirty gallons of such liquor produced from every ton of coals. The average price of ammoniacal liquor of eight ounces strength in eleven towns of England is at the present time 2s. 7d. per butt of 108 gallons. It ranges from 1s. 9d. to 4s. 6d. per butt, and in London it fetches 2s., with an increase of 4d. per butt on every additional ounce of acid.

strength. Below 3° of Twaddle or five ounces of acid it does not pay for working, whereas at 10° or 11° of Twaddle it is a valuable product. The strength of the liquor may be estimated either by the hydrometer or by the quantity of strong sulphuric acid (sp. gr. 1.845) required to neutralize it; and it will be found that every degree of Twaddle is equal to about two ounces of acid per gallon of liquor.

The method of converting the liquid into a salt of ammonia varies in different places according to the facilities for working. In some places the liquor is at once saturated either with sulphuric or muriatic acid, in a close tank, and the evolved gases (sulphuretted hydrogen and carbonic acid) are carried to a furnace or to a furnace shaft. The saturated liquor is then evaporated and crystallized in open troughs. This, however, produces a dark-colored salt which is not very salable. The liquor, therefore, is either distilled alone from a steam-boiler, or it is mixed with lime in the boiler, so as to fix the sulphuretted hydrogen and carbonic acid, and is then distilled. In many works the liquor is heated in an apparatus called a Coffey's still, which is a tall vessel containing a number of transverse divisions (from twenty to thirty) which alternately pass to nearly the opposite sides of the vessel. The liquor is run in at the top, and as it flows from side to side over the alternate divisions, in its way downward, it meets a rush of steam, which is admitted at the bottom of the vessel, at a pressure of from twenty to thirty pounds upon the inch, and thus the carbonate and sulphide of ammonium are volatilized. In all these cases the ammonia is distilled into a close vessel containing sulphuric acid, diluted with enough water to prevent the salt from crystallizing, (equal parts of brown chamber acid of commerce and water are good proportions;) and the evolved gas (carbonic acid and sulphuretted hydrogen) is conveyed to the furnace fire, or is used for the production of oil of vitriol. When the ammoniacal liquid is evaporated by blowing steam into it, it is necessary to have a worm, or other cooling apparatus, to condense the water from the gases before they are carried to the furnace, or they will, perhaps, extinguish the fire. While the distillation is going on the acid in the saturating vessel is frequently examined, and when it is thoroughly neutralized it is run out into a proper receiver, and is then transferred to shallow pans or troughs, where it is evaporated to the crystallizing point.

The residual liquor from the stills is not completely exhausted of ammonia, but contains from three to five ounces of sulphocyanide of ammonium per gallon. It is, therefore, treated with lime, and again distilled, whereby more ammonia is obtained.

If there were a large demand for the sulphocyanide, it might perhaps be worth while to recover it from the spent liquor, by evaporation, especially where it could be done by waste heat. Here is some of the residual liquor, and you will notice that when I add to it a very acid solution of a persalt of iron it produces a deep blood-red color of the ferric-sulphocyanide. Here also is some of the salt obtained from the

liquor by evaporation, and it is well suited for the preparation of this white powder, the mercuric sulphocyanide, which is the sole constituent of the little toys called Pharaoh's serpents. Sulphocyanide of ammonium is also used to some extent by photographers. I may here mention that the watery solution which runs from the hydraulic mains with the tar, when the temperature is not below 150° F., contains this salt, without any carbonate or sulphide of ammonium; there is no reason, therefore, why this solution may not be collected, apart from the true ammoniacal liquor which is found in the condensers, for even if it be not of much value on its own account, it might be kept from diluting the liquor in the first stages of condensation, and be afterward used instead of water for finally washing the raw gas.

In country gas works, where there is little or no sale for ammoniacal liquor, it would not be difficult to convert it into sulphate of ammonia, by transferring it to an old boiler, then blowing steam into it, and carrying the vapors into a properly constructed vessel, charged with the brown sulphuric acid of commerce, diluted with the mother liquor of a previous crystallization. In this way every ton of coals should yield about thirty pounds of sulphate of ammonia.

This sulphate is worth from £12 to £14 per ton, and it is not merely used for agricultural purposes, but it is the salt from which all other preparations of ammonia are obtained. Distilled with quicklime it yields pure ammonia, which by condensation in water forms the liquor ammonia of commerce; distilled with chalk it makes carbonate of ammonia; and it has other applications. There are good reasons, therefore, why great pains should be taken to recover all the ammonia of gas-making. We shall presently see how this may be further accomplished by means of absorbent agents placed at the end of the purifiers.

III.—COAL TAR.

This is a very complex liquid, for it contains at least three classes of compounds, viz: acids, neutral bodies, and alkaloids, the composition and leading properties of which are as follows:

Acids of coal tar.

Names.	Formulæ.	Specific gravities.	Boiling points, (F.)
Acetic	C ₂ H ₄ O ₄	1062	243°
Butyric	C ₃ H ₈ O ₄	973	314
Carbolic	C ₁₂ H ₆ O ₂	1065	370
Cresylic	C ₁₄ H ₁₀ O ₂	.....	397
Phloryllic	C ₁₆ H ₁₀ O ₂	.....	424
Rosolic	C ₂₄ H ₁₂ O ₆	.....	.....
Bromolic .....	?	.....	.....

Neutral bodies of coal tar.

Names.	Formulae.	Specific gravities.	Boiling points, (F.)
Alliaceous oils.....	?	?	?
Benzole.....	C ₆ H ₆	850	177
Tolnole.....	C ₈ H ₈	870	230
Xylole.....	C ₁₀ H ₁₀	867	264
Cumole.....	C ₁₂ H ₁₂	870	299
Cymole.....	C ₁₄ H ₁₄	861	341
Naphthaline.....	C ₁₀ H ₈	1153	428
Anthracine.....	C ₁₆ H ₁₀	1147	572
Pyrene.....	C ₁₈ H ₁₂	.....	?
Chrysene.....	C ₂₀ H ₈	.....	?

Basic or alkaline bodies of coal tar.

Pyridine.....	C ₅ H ₅ N	986	242
Pyrrol.....	C ₅ H ₅ N	1077	272
Picoline.....	C ₈ H ₇ N	961	271
Lutidine.....	C ₁₀ H ₉ N	946	310
Collidine.....	C ₁₂ H ₁₁ N	937	354
Parvoline.....	C ₁₃ H ₁₃ N	.....	370
Aniline.....	C ₆ H ₅ N	1080	360
Toluidine.....	C ₇ H ₉ N	.....	388
Xylidine.....	C ₈ H ₁₁ N	.....	418
Cumidine.....	C ₁₀ H ₁₃ N	952	437
Cymidine.....	C ₁₂ H ₁₅ N	.....	482
Chinoline.....	C ₁₀ H ₇ N	1081	462
Lepidine.....	C ₁₂ H ₉ N	1072	510
Cryptidine.....	C ₁₄ H ₁₁ N	.....	525

The general properties of coal tar, as well as the proportions of its several constituents, vary with the quality of the coal used, and with the temperature at which it is distilled or carbonized. The tar which is produced from common gas coals at rather high temperature is always heavier than water, (sp. gr. 1.120 to 1.150.) It dries freely in the air, and its hydrocarbons are so rich in carbon that the tar cannot be burnt in an ordinary lamp. But the tar which is produced from cannel coal at lower temperatures is lighter than water, and does not readily dry when it is exposed to the air. Besides which, its hydrocarbons are comparatively poor in carbon, and may be burnt in lamps. There is almost every variety of coal tar from these two extremes, but the tars of commerce are chiefly of three kinds, viz: the rich cannel coal tar of Scotland, the tar which is produced from common coal in country gas works, where

the temperatures are generally low, and the still heavier tar of the London gas works, which is produced at excessively high temperatures. The yield of tar, per ton of coals, is from nine to fifteen gallons, the latter being the average at country works; and the former, or from that to ten gallons, is the yield in London, where the tar is undoubtedly affected by the high temperature of the retorts; for it is not only small in quantity, but it is deficient of naphtha, and contains more pitch than country tar, besides which the dead oil from it is always overloaded with naphthaline.

In London the distillation of coal tar is always effected in stills, which are placed over a fire, and the products are collected at different stages of the distillation. Up to a temperature of from 160° to 190° F. little or nothing flows over; but at that temperature ammoniacal liquor, with crude naphtha of a gravity of .850, begins to distil. These continue to flow until the thermometer rises to from 310° to 340°, when a heavier naphtha, of a gravity of about .920, is carried over. This is called light oil, and it is collected separately until the temperature rises to from 370° to 400°, and then the oil begins to have the gravity of water; after that, and up to the temperature of from 690° to 700°, the oil which is collected is heavier than water, and is therefore called heavy or dead oil, the last runnings having a gravity of 1.060 or thereabouts. If a soft pitch is wanted, the process of distillation is stopped at this stage; but if a harder pitch is required it is pushed a little further, and the green oil which flows over is rich in neutral oils, which are well suited for making railway grease.

A still containing 2,500 gallons of coal tar will in this way yield about the following proportions of the several products:

Ammoniacal liquor, from 50 to 70 gallons; average, 60 gallons.

Crude naphtha, from 30 to 50 gallons; average, 40 gallons.

Light oil, 12 to 35 gallons; average, 30 gallons.

Creosote or dead oil, 689 to 740 gallons; average, 720 gallons.

Pitch, 8 to 10 tons; average, 9 tons.

Each of these products has its commercial value, the naphtha and light oil being used for the production of benzole and toluole of commerce—naphthas which are largely in demand for the manufacture of coal-tar colors.

Formerly the greatest value was attached to the naphtha or benzole which had a low boiling-point, and the contracts, especially with the French, were for a benzole or naphtha which yielded ninety per cent. of volatile oil at a temperature not exceeding 212°, and I have examined thousands of gallons of this quality for the French market. Even at the present time there is a demand for this, which is called ninety per cent. benzole, for making certain aniline reds; and to obtain it the crude naphtha, or the first runnings from the tars, were distilled alone. At present, however, there being a demand for a less volatile oil, the practice is to mix together the crude naphtha and the light oil, and to subject them to fractional distillation, thus: steam is blown into them at a pressure of twenty to thirty pounds on the inch, and the naphtha which

comes over with the steam is called "once-run naphtha." This is purified by shaking it with strong sulphuric acid, (sp. gr. 1.845,) using the acid in small proportions at a time, for fear of injuring the naphtha, and washing with water between each operation. In this manner, after using about five per cent. of acid, (or one-half pound to each gallon of naphtha,) the brown coloring matter of the naphtha and all basic compounds are either destroyed or removed, and the brown naphtha, after being well washed with water, is again distilled by blowing high pressure steam into it, and the products are collected at three stages; that which comes over first is called crude benzole of eighty per cent. strength, the second runnings are a naphtha containing fifty per cent. of benzole, and the third is a naphtha which is used for solvent purposes. With a view of strengthening the fifty per cent. benzole, and making it eighty per cent., it is redistilled from a vessel with a steam jacket, whereby the temperature can be regulated. That which flows over at a temperature up to 210° is set aside as eighty per cent. benzole; that which distils between 210° and 260° is called thirty per cent. naphtha; and the residuum, on being treated with high-pressure steam yields solvent naphtha. Once more, the thirty per cent. naphtha, or that which has flowed over at from 210° to 260° , is distilled with a dry steam heat, and when the thermometer has risen to 106° there is obtained a little more eighty per cent. benzole; after which, and up to 234° , there flows over what is called forty per cent. naphtha, and from 234° to 260° a little of the thirty per cent. Steam is then blown into it, and it yields a little of the solvent naphtha.

In this way, by a series of fractional distillations, the washed naphtha is made to yield at each successive operation a quantity of eighty and forty per cent. naphtha. All the eighty per cents. are then mixed together, and are once more distilled by a dry steam heat. The naphtha which flows over at a temperature up to 204° is called ninety per cent. benzole; that which flows between 204° and 210° is called eighty per cent. benzole, and is again fractionally distilled up to 204° ; while the residue, on being treated with high-pressure steam, yields a quantity of forty per cent. naphtha.

Five separate products are thus obtained, namely, ninety per cent. benzole, forty per cent. benzole, solvent naphtha, the last runnings of the first operation, and the residuum of each distillation. Operating in this manner with a charge of 1,587 gallons of crude naphtha and light oil, there is first obtained 897 gallons of once-run naphtha and 56 gallons of the last runnings, the remainder (634 gallons) being a residuum of no value except for mixture with dead oil; and the 897 gallons of once-run naphtha yields, after it has been purified with sulphuric acid, 301 gallons of ninety per cent. benzole, 195 gallons of forty per cent., 237 gallons of solvent naphtha, 12 gallons of last runnings, and 152 gallons of residuum.

The forty per cent. benzole contains also fifty per cent. of volatile oil, chiefly toluole, which distils over between 212° and 248° . This is the oil which is preferred at the present time for the manufacture of coal-tar colors. The several products which are thus obtained in the distillation

of coal-tar are upon the table before you, and, roughly speaking, the proportions per 10,000 gallons of crude tar and their commercial values are as follows:

Forty per cent. benzole, 34.4 gallons, worth 2s. 4d. per gallon.

Ninety per cent. benzole, 53.1 gallons, worth 2s. per gallon.

Solvent naphtha, 41.8 gallons, worth 1s. 9d. to 2s. per gallon.

Last runnings, 12 gallons, worth 9d. per gallon.

Dead oil, 3,018.7 gallons, worth 1d. per gallon.

Pitch, 36 tons, worth 45s. per ton.

Before rectification the crude naphtha is worth about 1s. per gallon, and the light oil about 6d., the two together fetching 9d. or 10d. a gallon; and once-run naphtha is worth 1s. 6d. a gallon. Two samples of this oil from different distillers yielded by fractional distillation the following percentage of proportions of oil at different temperatures:

Yield of oil by fractional distillation.

	Sample 1.	Sample 2.
Up to 212° Fahrenheit.....	15.0	17.5
From 212° to 248°.....	44.0	42.0
From 248° to 264°.....	8.0	8.5
From 264° to 300°.....	13.0	13.0
From 300° to 320°.....	5.5	4.5
Residuum.....	14.5	14.5
	100.0	100.0

The samples, therefore, in commerce from good markets may be regarded as of pretty uniform quality.

In Scotland the method of distilling coal tar is a little different from what it is in England, and this arises from the circumstance that the Scotch cannels yield a tar which is so rich in the volatile naphthas that it is not altogether safe to distil the tar from a still with a naked fire. The tar, therefore, is first submitted to the action of high-pressure steam, which is blown into it until the more volatile products are passed off. In this way from seven to thirteen per cent. of crude or rough naphtha is obtained with a gravity of about .930. The residuum is called boiled tar, and is distilled with a naked fire. It thus yields from six to seven and a half per cent. of a light oil called pitch oil or torch oil, which has a specific gravity of from .973 to .976. The next runnings, which amount to from twenty-seven to thirty per cent. of the boiled tar, are generally heavier than water, and are called heavy pitch oil, and they constitute the great bulk of the product.

The several products of coal tar are thus used in the arts:

COAL TAR is itself employed as a rough varnish for iron, and in Scotland the boiled tar is extensively used for covering woodwork, &c.

LIGHT OIL AND CRUDE NAPHTHA are either redistilled for procuring benzole and toluole, as I have already explained, or they are employed for making common black varnish, or for burning in naphtha lamps. In

this country they are for the most part distilled, but in Scotland they are largely used in a lamp called the foundry lamp. It is an enlarged form of a lamp which was patented many years ago by Mr. Beale, and it consists of a chamber supplied with naphtha, and having a nozzle or jet for directing a blast of air through it. The chamber is covered with a bell with a large hole in the top of it. When the naphtha is lighted and the bell put upon it, the blast of air forces the vapor of the burning naphtha through the hole in the top of the bell, and thus produces an enormously large volume of flame. The light is equal to at least a dozen gas jets, and the cost of it is said to be a penny a night. It is very generally used in the foundries, the ship-yards, and other large workshops of Scotland.

SOLVENT NAPHTHA is a colorless spirit, which is chiefly employed for dissolving India-rubber for waterproofing, and resins or pitch for varnishes.

The last runnings are also used for varnishes, for making a superior lampblack called spirit black, and for burning in Holliday's lamp, which is the common naphtha lamp of the streets. It is an ingenious contrivance for converting the naphtha into vapor by means of a mass of heated metal and spreading it out in a star-like form.

I have already alluded to the use of coal naphtha as a means of increasing the illuminating power of common twelve or fourteen candle gas, and have shown that with a moderately good naphtha, which yields about seven grains of vapor to every cubic foot of gas, the illuminating power may be increased about sixty per cent. Considering that naphtha is now becoming a drug in the market, from the waning of fashion in respect of coal-tar colors, it may be worth while to encourage its use as a naphthalizer, rather than to yield to the public clamor for cannel gas. I have long thought that gas, as well as water, should be dealt with at the consumers' houses, when in either case it is required to be of unusual quality.

THE CREOSOTE, OR DEAD OIL OF COAL TAR, is used almost entirely for the preservation of timber, and at the present moment, in the stagnant condition of railway business, it is almost unsalable. I apprehend, however, that it is valuable as a fuel, and that it will ere long be used in steam furnaces. Already there are several patents for its application in this manner, and experiments are now being conducted at Woolwich with the view of ascertaining its practical and economical capabilities. The contrivances which appear to offer the largest prospects of success are those which deliver the oil into the furnace in the form of a spray or vapor, by means of a jet of steam or blast of hot air; and it is said that the heating power of the oil is from two and a half to three times that of a similar weight of coal.

In applying the oil to the preservation of timber, it is necessary that it should be forced deeply into the tissue of the wood. The method employed by the best operators is to place the timber in large wrought-iron cylinders, and then to exhaust it of air and moisture as completely as possible by creating a vacuum. After a time the dead oil, heated

to a temperature of 120° F., and thus made as fluid as possible, is let into the cylinder. Pressure is then put upon it until the oil is forced into the wood with a power of 150 pounds upon the inch. In about three hours the wood absorbs the prescribed amount of creosote, which, with the best houses, is never less than from thirty pounds to fifty pounds of creosote to a load of fifty cubic feet of timber; every cubic foot of timber has, therefore, taken up from six pounds to ten pounds of oil.

The preservative power of the dead oil is partly due to the antiseptic properties of the creosote and partly to its filling up the pores of the wood with an oil which gradually resinifies and excludes air and moisture. Different views are entertained of the quality of creosote which is best suited for this purpose. In the contracts which I have prepared for the Indian railway works I have prescribed that the creosote should have the following properties: "It should have a density between 1.045 and 1.055; it should not deposit any crystalline matter at a temperature of 40° F.; it should yield not less than five per cent. of crude carbolic acid to a solution of caustic potash of the density of 1.070 (14° Twaddle); and it should furnish ninety per cent. of liquid oil when distilled to the temperature of 600° F." The contracts, which I have lately seen, for the Dutch government prescribe that the creosote shall be clear and shall not deposit more than forty per cent. of naphthaline when cooled to the temperature of 32° and kept at that temperature for twenty-four hours. Here are specimens of creosote from country tar which fully realize those properties; but this sample from London tar is almost solid at 32° .

Another use to which dead oil has lately been put is the preparation of a dip for washing sheep. It was patented by Mr. M'Dongal in 1860, and is made by heating together two parts by weight of dead oil with one of a solution of caustic soda of 50° Twaddle, (sp. gr. 1.250,) which contains about fifteen per cent. of soda; and to this is added one part of tallow, fat, or other saponifiable substance. The mixture which is thus obtained has the appearance of a very dark soft soap, and it is either smeared upon the skin of the animal or dissolved in water and used as a wash.

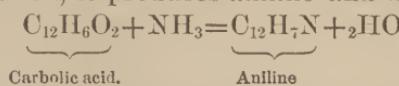
THE GREASY MATTER, OR GREEN OIL, which follows the dead oil in the distillation of coal tar, is used for making railway grease, with resin, oil, &c.; and the pitch which is the residual product of the distillation is largely employed for all sorts of purposes.

Looking, therefore, at the compositions of the principal products of coal tar distillation, it may be said that the crude naphtha contains certain alliaceous oils, with benzole, toluole, xylole, cumole, and a little cymole, besides the more volatile basic compounds, as pyridine, picoline, lutidine, collidine, and a little aniline, with from two to three per cent. of carbolic acid and a little naphthaline.

LIGHT OIL contains cumole, symole, and the other less volatile hydrocarbons, with a large amount of naphthaline, and the denser alkaloids, as collidine, aniline, toluidine, and even a little chinoline; besides which it contains from ten to twenty per cent. of carbolic and cresylic acids.

HEAVY OIL consists chiefly of hydrocarbons which have not been well studied, and the bases which have a high boiling point, as chinoline, lepidine, and cryptidine, with small quantities of emidine and cymidine, and from seven to ten per cent. of carbolic and cresylic acids.

CARBOLIC ACID ($C_{12}H_6O_2$), or, as it is sometimes called, phenic acid, is largely in demand for making dyes and for disinfecting purposes, and it is most profitably extracted from the light oil before it is distilled for benzole, &c. The naphtha which flows over between 300° and 400° F., and which has gravity below 900, is best suited for the preparation of carbolic acid; for although there is much acid in the heavier oils, yet they are so nearly of the same gravity as the alkaline solution used in extracting it that there is great difficulty in separating them. The light oil is well shaken with about one-third of its bulk of a solution of caustic soda of from 14° to 16° Twaddle (1.07 to 1.08 sp. gr.) and containing from five to seven per cent. of alkali. After standing for some time the oil separates, and the alkaline liquor may be drawn off by means of a siphon. This is to be neutralized with sulphuric or muriatic acid, and then the carbolic acid floats as a dark brown oil. This is the crude acid of commerce, and when purified by means of sulphuric acid and careful distillation from chloride of calcium, it forms the camphor-like substance which you here see. It has a peculiar creosote-like smell, and when largely diluted with water, even to the extent of 1 part in 10,000, it has a sweet taste. It is a very powerful caustic, turning the skin white and quickly raising a painless blister. The specific gravity of the pure acid is 1.065. It melts at from 95° to 98° F., but the merest trace of water will lower its melting or congealing point, so that this is the test of the quality of the acid. It boils at 369° or 370° F., and its vapor burns with a sooty flame. If it be passed through a red-hot tube it is decomposed, forming naphthaline and other hydrocarbons; and if it be heated for some time with ammonia in a closed tube, at a temperature of from 400° to 500° F., it produces aniline and water thus:



It combines with alkalies to form salts, but the combination is very feeble, for the acid is set free by heat and even by the carbonic acid of the atmosphere, so that the common preparation of it, carbonate of lime, slowly evolves carbolic acid when it is exposed to the air.

The acid is a very powerful antiseptic and disinfectant. It is especially destructive of the lower forms of organic life, and hence, perhaps, its value as a disinfectant. Several varieties of the acid are now prepared and sold for general and medical purposes, and the experience of the last few years has proved it to be an important hygienic agent. Its use in the preparation of dyes will be explained directly.

The other acids of coal tar, as *cresylic*, ($C_{14}H_8O_2$), *phlorylie*, ($C_{16}H_{10}O_2$), *rosolic*, ($C_{24}H_{12}O_6$), may be obtained by the use of a stronger alkaline solution as recommended by Laurent. A saturated solution of potash,

added to the mixed light oil and heavy naphtha, and then treated with a little powdered caustic potash, will produce a magma from which the unattacked liquid oil may be separated. By dissolving it in a small quantity of water and allowing it to stand, it separates into two layers—an upper, oily layer, which is of no use, and a lower layer which contains the tar acids. When this is neutralized with muriatic acid, the crude acids float as an oily layer, and may be separated from each other by fractional distillation.

IV.—SPENT OXIDE OF IRON.

This is the next substance in order of the purification of coal gas. In its fresh state the hydrated peroxide of iron freely absorbs the sulphuretted hydrogen of foul gas, forming the black sulphide of iron. On exposure to the air the iron again absorbs oxygen, and becomes revived, the sulphur which it had before taken in as sulphuretted hydrogen being set free among the particles of the oxide. In this manner, by a succession of foulings and revivifications, the oxide becomes so charged with sulphur as to be unfit for use. It then contains from thirty-five to fifty-seven per cent. of sulphur, the average being about forty-two per cent.; and although it is useless at the gas works, it is of some value in the production of oil of vitriol. Special furnaces, however, are necessary for its combustion, for as it contains about twenty per cent. of sawdust it is not capable of being used in ordinary sulphur furnaces. At Messrs. Lawes and Messrs. Hills, where I have seen the spent oxide largely used for making sulphuric acid, the furnaces are constructed with very long flues, for the purpose of completely burning the organic vapor before it enters the vitriol chamber. Each furnace is about twelve feet long and eighteen inches square, with a floor of fire-brick, upon which the oxide burns. It takes about two and one-half ewt. of oxide at a charge, and it burns continuously for twelve hours. The air is admitted by a sliding door in front, and the gaseous products are conveyed from the furnaces, which are placed side by side, and in three tiers over each other, to a common flue at the back, and this is extended backwards and forwards, below and above, so as to prolong the combustion to the greatest extent before the vapors enter the vitriol chamber, for if the combustion is not complete there is a considerable waste of nitre; as it is, indeed, the quantity of nitre used for the oxidation of the sulphurous acid is always about half as much more as is required with native sulphur or pyrites. I think the process might be very considerably improved by continuous instead of intermittent burning, and there is no reason why the use of sawdust may not be abandoned altogether, and spent oxide employed in its place.

V.—SPENT OR REFUSE LIME.

This is generally a very profitless material—in fact, the blue billy from the wet-lime purifiers is incapable of any sort of application but that of

luting. Dry lime, however, is not so unmanagable a product, for if it is treated properly it need not occasion offense; and when it is well weathered it is of some value to the farmer. Professor Voeleker has inquired very fully into this matter, and he states that it is useful to certain soils on the following account:

1. It improves the texture of stiff clay soils by lightening them, and of light sandy soils by giving them solidity.
2. It neutralizes the acidity of some soils, and breaks up the organic matter of soils which are too rich in humus, making them more fit for the sustenance of plants.
3. It acts on the granitic constituents of a soil, and sets free the alkalies, thereby making the mineral elements of it available as food for the plant.
4. It supplies food to the plant in the form of sulphate of lime, which is especially useful to the leguminosæ.

And he concludes that well-weathered gas lime, judiciously applied to a proper soil, is most useful to many plants, as clover, sainfoin, lucerne, peas, beans, vetches, and turnips; and that it is a good fertilizer, for permanent pasture, especially if the land is deficient of lime. On natural grasses the best farmyard manure often produces but little improvement until a dressing of lime, marl, or gas lime has been applied to it; the latter, more particularly, destroys the coarser grasses, and favors the growth of a sweeter and more nutritious herbage. It also destroys moss, heath, feather-grass, and other plants which are characteristic of peaty land. It is, therefore, especially suited for the improvement of such land; and so it is for the land which is deficient of lime, and which causes turnips to become warty, and be affected with the disease called "fingers and toes." For this it has been found a complete remedy. It may be applied in quantities of from one to two tons an acre, and even more where lands are very heavy, or are very peaty; and the best time to apply it is in the autumn, when vegetation is dormant, so that it can not only weather before the spring returns, but also act on the land during the whole of the winter.

One special precaution is that the lime should never be used in its fresh state, when it contains sulphide and sulphite of calcium in such proportions as to be injurious to plants. The more it is oxidized the better, and, therefore, when it is drawn from the purifiers it should be covered with old material, so as to prevent smell, and kept until it has lost its activity. The fresh lime contains from fifteen to twenty-five per cent. of quicklime, with a large proportion of sulphide, carbonate, and sulphocyanide of calcium; and even after six or eight months it may still contain a notable proportion of quicklime, with from twenty to thirty per cent. of sulphate of lime, a like proportion of sulphite of calcium, and still more of carbonate, in which condition it is not injurious to plants.

In many places farmers are glad to have the material, and will give as much as 2s. a load for it, although the common price is about 1s. a load.

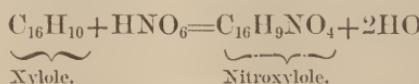
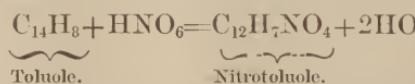
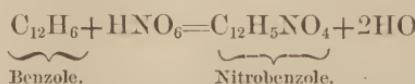
VI.—ACID AND OTHER ABSORBENTS OF AMMONIA.

At the end of all the purifiers there may be placed the material which has been patented by Messrs. Sugden and Maryatt. It is made by moistening sawdust with sulphuric acid slightly diluted with water, and heating it in a retort. The woody matter is in this way charred by the acid and contains from thirty to forty-five per cent. of free sulphuric acid. When it is exhausted by being charged with ammonia, it contains forty to sixty per cent. of salt, which is easily washed out of it, leaving the charred sawdust ready for another charge of acid. The material, with the sulphate of ammonia in it, is fit for conversion into manure, and is worth £5 or £6 per ton. Another absorbent of a like nature is that used by Mr. Croll. It is made from the spent chloride of manganese from the bleaching works by adding it to chalk and sawdust, and, when saturated with ammonia, it contains from thirty-nine to forty per cent. of muriate of ammonia, which is easily obtained from it either by washing or subliming.

These are several waste products of the manufacture of gas, and it will be seen that in the aggregate their value is not inconsiderable, provided they are utilized to the fullest extent.

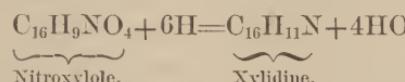
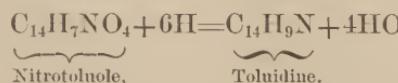
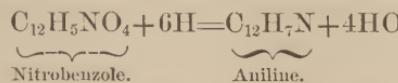
COAL-TAR COLORS.

I will now make a few remarks on the processes which are followed for the production of coal-tar colors. Most of them are derived from the naphtha which is sold as forty per cent. benzole, which is a mixture of benzole and toluole with a little xylole. The first step of the process is to convert the constituents of this naphtha into the corresponding nitro-compounds, by carefully mixing it with fuming nitric acid or with a mixture of two parts of common nitric acid and one sulphuric. The reaction is very violent if the temperature is not controlled; but, with proper management, the three hydrocarbons lose each an equivalent of hydrogen to a like proportion of oxygen in the nitric acid, and gain the residual peroxide of nitrogen. Thus:



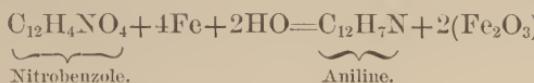
These three nitro-compounds constitute the dark amber-colored, oily liquid which floats upon the acid; and when it is separated from the acid and washed with water, and then with a weak solution of carbonate of soda, it constitutes the crude nitrobenzole which is used for the manufacture of aniline colors.

It has a strong odor of bitter almonds, is heavier than water, and is very soluble in alcohol and ether. If this crude nitrobenzole be submitted to the action of a reducing agent, each of the nitro-compounds will lose its four equivalents of oxygen, and gain two of hydrogen, and be thereby converted into a corresponding alkaloid, thns:



This process of reduction may be effected by sulphide of ammonium, (Ziniu's method,) or by the nascent hydrogen evolved when zinc is treated with dilute sulphuric acid, (Hofmann's method,) or by acting on the nitro-compounds with iron and acetic acid, (Bechamps's process.) I show you here an experimental illustration of each of these processes, and you will observe that for lecture experiment the process of Hofmann is the most striking, but in practice the method of Bechamps is the most economical.

One hundred parts of the crude nitrobenzole is mixed with nearly its own weight of strong acetic acid, and to this is added little by little about 150 parts of iron turnings. The mixture is generally made in an iron retort, and after being well stirred it becomes hot, and soon forms a pasty mass of oxide of iron with an acetate of aniline and the other bases. The reactions are somewhat intricate, but they may be practically expressed thus—



And the same for the other nitro-compounds, so that theoretically the acetic acid should act indefinitely.

The mixture is then submitted to heat until the retort is nearly red hot, by which means impure aniline, &c., distils over, and when this is treated with a slight excess of lime or soda, and again distilled, it yields the crude aniline of commerce. The best product is obtained when the distillation is going on between the temperatures of 340° and 380° , for as the temperature rises to 626° two new alkaloids are produced, which Hofmann has named paraniline ($\text{C}_{24}\text{H}_{14}\text{N}_2$) and xenylamine ($\text{C}_{24}\text{H}_{11}\text{N}$.)

Other processes have been suggested for the production of aniline and its homologues from the nitro-compounds; thus Kremer has recommended the use of finely powdered zinc; Wöhler, an alkaline solution of arsenious acid; Wagner, the ammoniacal solution of suboxide of copper; and Vohl, an alkaline solution of grape sugar; but none of these methods have taken the place of Bechamps.

The crude aniline of commerce, which is a mixture of aniline and toluidine, is more or less deeply colored liquid of an amber tint; it is heavier than water, and it acquires a blue or red color by various oxidizing agents. A solution of chloride of lime turns it, as we see, of a bluish-purple color. It was this reaction which suggested the name of kyanol—blue oil. Acidulated with a mixture of equal parts of water and strong sulphuric acid, and treated with peroxide of manganese or peroxide of lead, it produces, as you observe, a rich blue. Chromic acid makes it, as you may see, of a green, a blue, or a black color, according to the degree of oxidation; but the most remarkable experiment of all is the coloration of the aniline when it is acidulated with dilute sulphuric acid and submitted to the action of the galvanic battery. At the platinum pole, where oxygen is evolved, it instantly becomes bronze-green, then blue, then violet, and finally red; showing that the coloration of the alkaloid is due to the nascent oxygen, and that the tint corresponds to the degree of oxidation.

The crude aniline dissolves to some extent in water, but it is more freely soluble in alcohol and ether. It readily combines with acids, and forms crystalline compounds; hence it was called crystalline by Unverdorben, its discoverer. These salts become colored on exposure to the air.

The production of colors from this liquid was the remarkable feature of the Exhibition of 1862. It dates from the year 1856, when Mr. Perkin discovered and patented the process for making a rich violet from aniline by means of bichromate of potash; but it is right to say that several chemists had long before noticed the fact that the salts of aniline were capable of producing rich colors. Runge, in 1835, obtained a violet blue by acting on one of the oily constituents of coal tar with chloride of lime. Five years afterwards Fritzsche observed the blue coloration of aniline with chromic acid, and the like thing was described by Beisenhirtz; but none of these reactions commanded attention until the year 1859, when Messrs. Guinon, Marnas, and Bonnet, of Lyons, introduced a new fast purple under the name of French purple, which they obtained from orehil, and which became a favorite and fashionable color. The mauve of Mr. Perkin, which had been for three years before the public, was so much like it, that it rose suddenly into public favor. The year after, in 1859, M. Verguin, of the firm of Rénaud Brothers, of Lyons, obtained a brilliant red from the same base, and it was patented by them under the name of fuchsine. These two results commanded so much attention that the scientific and technical world entered very earnestly into the investigation with the view of discovering new processes of manufacture; and at the present time we have the means of making almost every variety of tint from coal-tar products. Most of these dyes are called aniline colors, but in truth they are produced from toluidine as well as aniline, and, as we shall see hereafter, they are obtained by processes of oxidation and substitution. They are generally classified under the heads of violets, reds, blues, greens, blacks, yellows, &c.

VIOLETS.

These have received a variety of fanciful names, as manve, violine, rosolane, tyraline, indisine, harmaline, imperial violet, regina purple, &c., &c.

The first of them was obtained in 1856 by Mr. Perkin, whose patent is dated the 26th of August of that year. His process is to add equivalent proportions of diluted solutions of a salt of aniline (generally the sulphate) and bichromate of potash. A good proportion is two parts by weight of aniline, two of bichromate of potash, and one of sulphuric acid of English commerce. The aniline and sulphuric acid are first mixed and then dissolved in water. To this solution is added the bichromate of potash, also previously dissolved in water, and after being well stirred they are allowed to remain quiet for ten or twelve hours, when a dark-colored sediment appears. This is to be collected upon a filter and well washed with cold water. It is then dried and treated with colorless coal-tar naphtha until all brown, tarry, and resinous matter is dissolved away. After this it is again dried and boiled in successive portions of alcohol or methylated spirit until the whole of the violet coloring matter is dissolved out. The spirit solutions are then distilled in order that the spirit may be recovered, and the residue is mauve. It amounts to only about four or five per cent. in weight of the aniline used, but its tintorial power is very great. In this condition it is not absolutely pure, although it is sufficiently so for common purposes. To purify it, it must be boiled in a large quantity of water, and the solution treated with an alkali. The coloring matter which precipitates is to be collected upon a filter, washed with water until all trace of alkali is removed, and then dissolved in spirit. If the spirituous solution be evaporated to dryness, the pure coloring matter remains as a beautiful bronze-like substance. It is hardly at all soluble in water, ether, or coal-tar naphtha; but it freely dissolves in spirit and in weak acids, especially acetic. Concentrated sulphuric acid dissolves it without decomposing it, and forms a dirty green solution, which becomes of a beautiful blue color with a little water, and a violet or purple with a good deal. It is, therefore, a very permanent body, although it will not resist the action of chlorine or nitric acid. Reducing agents, as sulphide of ammonium or protosulphate of iron, change it to a brown-colored solution, which reacquires its violet tint on exposure to the air. Like most of the aniline dyes it forms a very insoluble colored precipitate with tannin.

Other processes have been patented for making this color; thus, Bolley, in 1858, Beale and Kirkham, in 1859, and Depouilly and Lanth, in 1860, patented the use of chloride of lime with a salt of aniline. These solutions, when used in proper proportions, produce an insoluble purple precipitate, which is the manve of Perkin. It is purified by washing it with water slightly acidulated with sulphuric acid, then dissolving it in concentrated sulphuric acid, reprecipitating with water, washing it with

water upon a filter, and lastly dissolving in spirit. In 1859 Mr. Kay patented a process for obtaining it by adding peroxide of manganese to a strong solution of sulphate of aniline, and keeping the mixture for some hours at the temperature of boiling water. The purple solution thus obtained is to be filtered and precipitated by adding ammonia until the acid is neutralized, and the precipitate, when collected upon a filter, washed with water, and then dissolved in spirit, forms the violet-colored dye called harmaline. In the same year Mr. D. Price produced a patent for manufacturing the color by means of peroxide of lead instead of peroxide of manganese, and Mr. Greville Williams obtained a patent for permanganate of potash. The year after (1860) there were several patents for it, as Mr. Stark's, with ferricyanide of potassium, and Messrs. Dale and Caro's, with perchloride of copper and chloride of sodium.

In the year 1861, Mr. Adam Girard observed that a purple color could be obtained from aniline red by mixing it with its own weight of aniline and exposing it for several hours to a temperature of 350° Fahrenheit, which is a little short of the boiling point of aniline. The mixtures employed were equal parts of dry muriate of rosaniline and aniline, and the product, which is a reduced condition of aniline red, is washed with water slightly acidulated with muriatic acid until all the unacted on aniline and aniline red are removed, and the pure purple remains. This is dissolved in spirit of acetic acid, and forms the dye called Imperial purple. In the year following, (1862,) Mr. Nicholson obtained his patent for procuring the same color by merely heating magenta or aniline red to a temperature of from 390° to 420° Fahrenheit. The substance first melts, and, after evolving ammonia, is changed into the purple which he named *Regina* purple.

ANILINE REDS,

called fuchsine, roseine, azaleine, rosaniline, Magenta, Solferino, and other fanciful names, are conspicuous in the American section of the Paris Exhibition of this year. This color was obtained by Dr. Hofmann as far back as the year 1843, when he was experimenting on aniline with fuming nitric acid; and fifteen years later, in 1858, he again obtained it, when he was studying the reactions of bichloride of carbon on aniline. He found, indeed, that when three parts of aniline were heated with one part of bichloride of carbon for some time a resinous mass was produced, which furnished to alcohol a rich crimson color. This was aniline red; but, as he was studying the reactions for other purposes than the formation of colored products, he merely noticed the fact, and put it upon record. A year after Messrs. Verguin and Rénaud Brothers, of Lyons, discovered and patented their process for making fuchsine, or aniline red, from aniline, by means of bichloride of tin; and thus a practical value was given to the scientific researches of Dr. Hofmann. Fuchsine is obtained by heating together ten parts of aniline and six of anhydrous bichloride of tin in a glazed iron vessel for fifteen to twenty minutes. The temperature

should be about that of the boiling point of the mixture, (302° F.) At first the mixture becomes yellow, then gradually more and more red, until the liquid mass looks black. When this occurs it is allowed to cool, and the mass is treated with a large quantity of boiling water, which acquires a rich crimson color. This is the dye, and it may be used at once, or purified by adding to it a quantity of common salt, in which solution the dye is insoluble. The precipitated coloring matter is allowed to subside, and, after being collected upon a filter, it is dissolved in spirit, or acetic acid, and so forms the red dye. The process patented by Mr. David Price in the year following, (1859,) was to act upon a solution of sulphate of aniline with peroxide of lead, by boiling them together in the proportion of one equivalent of the former to two of the latter, until the solution acquires a deep red color. This is filtered, and, after being concentrated by evaporation, it is again filtered to separate a resinous substance which forms in it. An alkali is then added to neutralize the acid, and the coloring matter is precipitated as a dirty brown powder. When this is collected upon a filter, washed with water, and dissolved in spirit or acetic acid, it forms a beautiful red dye, which is fit for use. Messrs. Simpson, Maule, and Nicholson used this process very largely until the beginning of the year 1860, when Dr. Medlock committed to them his patent for making aniline red by means of arsenic acid. The process now followed is to mix together a highly concentrated solution of arsenic acid with aniline, using the latter a little in excess. A good proportion is twenty parts, by weight, of sirupy arsenic acid, containing seventy-six per cent. of the solid acid, and twelve of commercial aniline. In this manner a pasty mass of arseniate of aniline is formed, and, when this is heated for some time at a temperature of about 300° Fahrenheit, it intumesces, and at last forms a dark-colored liquid, which, on cooling, sets into a resinous solid, with a bronze-like luster. The crude coloring matter thus obtained is very soluble in spirit or water, and may be at once used for dyeing purposes, but it is better to purify it by adding a slight excess of slaked lime to the aqueous solution, and so precipitating the coloring matter with the insoluble arsenical salts of lime. The mixed precipitates are collected upon a filter, and the coloring matter dissolved out with acetic or tartaric acid. Another and better method of purification is to dissolve the crude mass in dilute muriatic acid; then to filter, and to precipitate by adding a slight excess of alkali, (carbonate of soda.) The color thus set free is to be collected upon a filter, washed with water, and then dissolved in spirit and acetic acid.

Another variety of aniline red, the nitrate of rosaniline, or azaleine, has been extensively manufactured in England by the process of Mr. Perkin, and in France by that of M. Geber Keller. Mr. Perkin heats a mixture of aniline, or its homologues, with dry pernitrate of mercury for some time at a temperature of 347° F. The mixture first becomes brown, and then gradually acquires a dark crimson color, during which time the mercury is reduced, and settles to the bottom of the

fused mixture. On pouring it off and allowing it to cool, it forms a solid mass of impure nitrate of rosaniline, which may be purified by dissolving in water, and precipitating with common salt. M. Gerber Keller's process is nearly similar, except that he uses a lower temperature. He takes ten parts of aniline and seven or eight parts of dry pernitrate of mercury, and heats the mixture for several hours in a bath of boiling water. Messrs. Dale and Caro obtain the color by heating a mixture of equal parts of aniline and powdered nitrate of lead, and then adding, little by little, a fourth part of anhydrous phosphoric acid. Other processes have also been patented, as that of Lauth and Depouilly, (1860,) with nitric acid; that of Smith, (1860,) with perchloride of antimony, antimonic acid, peroxide of bismuth, stannie, ferric, mercuric, and cupric oxides; and Gerber Keller has claimed almost every common metallic salt that is known. As might be expected, a number of these processes are practically useless, and have been claimed for no other purpose than that of anticipating the profits of future discoveries.

ANILINE BLUES,

called azaleine, Bleu de Paris, Bleu de Lyons, Bleu de Mulhouse, &c. Soon after the discovery of aniline red it was observed that certain reducing agents had the property, when heated with it, of changing its color to a purple or blue. Mr. Charles Lauth, for example, in 1860, described the blue color which was obtained from azaleine (nitrate of rosaniline) by means of protochloride of tin, aldehyde, the natural essences, &c.; and M. Kopp demonstrated that the same color was produced from aniline red by means of wood spirit. But as none of these colors were permanent, they were disregarded. In 1861 MM. Girard and De Laire procured their imperial purple in the manner already mentioned, by heating equal weights of aniline and dry muriate of rosaniline, at a temperature of about 350° F. for several hours. If the purple is wanted, the mass is merely treated with dilute muriatic acid until it loses its excess of aniline and aniline red; but if a pure blue is required, the acid treatment is continued until all the red tint is removed, and a pure blue remains. This is finally dissolved in acetic acid, or methylated spirit, and the blue dye, called Bleu de Lyons, is obtained. The same blue, but called Bleu de Paris, was procured by MM. Persoz, De Luynes, and Salvetat, by heating a mixture of aniline and dry bichloride of mercury in a sealed tube for thirty hours, at a temperature of 356° F. The mass when cold is dissolved in boiling water, and the color precipitated by means of common salt. This operation is repeated until the blue is quite free from the green pigment which accompanies it.

A blue, called Bleu de Mulhouse, may be obtained by the process patented by MM. Gros-Renaud and Schœffer in 1861, and which consists in boiling a solution of azaleine (nitrate of rosaniline) with gum lac and carbonate of soda for some time; and another blue, named azuline, has been produced by M. Marnas by a like treatment of a substance called

peonine, with eight times its weight of aniline; and the residuum is purified with a succession of solvents, as water acidulated with muriatic or sulphuric acid, then hot naphtha, then caustic alkali, and finally with water acidulated with muriatic acid. The azuline or blue color which remains is soluble in spirit, and forms a rich blue dye.

Blues are also produced by the action of numerous oxidizing agents on aniline or its salts, as by a solution of hypochlorous acid, (Hofmann,) by a solution of chlorate of potash and muriatic acid, (Fritzsche,) by peroxide of hydrogen, (Lauth,) by perchloride of iron or red prussiate of potash, (Kopp,) by peroxide of manganese or pernitrate of iron and hydrochloric acid, (Schenner-Kestner,) by bichromate of potash and acid, (Willm,) and I have obtained it by oxidizing the sulphate of aniline by means of the oxygen disengaged at the positive pole of a battery. In all these cases the blue is very difficult of solution, for it resists the action of every solvent but strong sulphuric acid. Taking advantage of this, Mr. Nicholson, in 1862, patented a process for purifying the blue coloring matter, by dissolving it in concentrated sulphuric acid, and then heating it for half an hour at a temperature of 302° F. By diluting it with water it is precipitated in a modified condition, for it is now soluble in pure water. Dr. Hofmann ascertained that it was a substitution compound of rosaniline, in which three equivalents of hydrogen had been substituted by three equivalents of a hydrocarbon, called phenyl ($C_{12}H_5$.) He therefore named it tryphenyllic-rosaniline; and this suggested the possibility of substituting other hydrocarbons, as methyl, (C_2H_3 .) ethyl, (C_4H_9 .) amy1, ($C_{10}H_{11}$.) &c., in which he was successful by acting upon rosaniline with the iodides of these radicals, and thus producing ethylic, methyllic, and amylic substitution compounds of a rich blue and purple color, called Hofmann's blues. Very recently the change has been effected by a more direct process, without the aid of the iodide, but by heating a mixture of aniline, muriatic acid, and methyllic alcohol under pressure, and then treating with iodine and chlorate of potash, or other oxidizing agent.

ANILINE GREENS.

Most of the blue substances just described become green by the action of acids, and again acquire a blue color when they are washed or treated with alkalies. It has also been noticed that in certain states of oxidation, aniline acquires a green tint; but all attempts to utilize this color failed until, in 1860, Messrs. Calvert, Clift, and Lowe patented the process for producing it upon the fabric. Their process was to prepare the fabric with chlorate of potash, and then to print upon it with acid muriate of aniline. In a few hours a beautiful bright green color, called emeraldine, gradually appeared, and it was fixed by merely washing it with water. If a blue tint were required, the fabric was passed through a solution of bichromate of potash, when the oxidation of the aniline

was carried still further, and a dark indigo-blue, called azurine, was produced.

A green color may also be obtained by heating a mixture of two parts fuchsine with three parts strong sulphuric acid and one part water. When the solution of the fuchsine is complete it is allowed to cool, and four parts of aldehyde are added. The mixture is again heated until it is a bright blue color without a trace of violet. It is then treated with a boiling solution of hyposulphite of soda, and filtered. The residue upon the filter is to be boiled in water, and filtered while hot. After standing twenty-four hours it deposits a green precipitate.

ANILINE BLACK.

Several processes have been proposed for making a black dye from aniline, as by acting on aniline with an oxide of chlorine, and then with a salt of copper; but the color is not of sufficient importance to command attention.

ANILINE YELLOW,

called chrys'aniline or phosphine. This color was first obtained by Mr. Nicholson in 1861. He procured it from the residuum of rosaniline by the action of steam, whereby a dirty yellow solution was obtained. On adding nitric acid to the solution, the yellow dye was thrown down as a nitrate of little solubility, and by decomposing it with an alkali the base is set free, which, either alone or in a form of a soluble salt, communicates a rich yellow color to silk and wool.

These are the principal colors obtained from aniline, and it may be of interest to examine the leading properties of these remarkable compounds. At first you will have remarked that the bases of nearly all the aniline colors are very insoluble in water, ether, and coal naphtha. They are more soluble in water acidulated with the mineral acids, and are still more soluble in acetic acid. Alcohol, however, is the great solvent for them. You will likewise observe that they are generally precipitated from their saline solutions by alkalies and by common salt, and in this manner they are generally purified. Tannin also produces an insoluble compound with them, and thus they are often fixed upon vegetable fabrics. They are endowed with great power of resistance, for they will bear the action of strong sulphuric acid without undergoing decomposition, but they cannot resist the action of powerful oxidizing agents, as chlorine, chloride of lime, or nitric acid. Reducing agents, as sulphide of ammonium and protosulphate of iron, destroy their color; but the action is not permanent, for on exposure to the air oxygen is absorbed, and the color reappears.

The bases themselves are not generally colored, but they acquire their characteristic tints when they combine with acids. I have here the colorless, or nearly colorless, solutions of rosaniline, mauvine, and aniline blue, and you will remark that directly I expose them to the vapors of an acid (acetic) their characteristic tints appear.

The tinctorial power of these dyes is remarkably great. If, for example, I put a little Magenta, mauve, or aniline blue upon paper, and then shake off the powder as completely as possible, there yet remains sufficient to give deep tints when I blow a fine spray of alcohol and acetic acid upon the paper.

The affinity of animal substances, as silk, wool, feathers, horn, ivory, leather, &c., is so great that the dye instantly combines with them, and produces a permanent stain. The affinity, indeed, is so great that, as you will see here, a piece of flannel will completely absorb and remove the coloring matter from its solution in water. Vegetable tissues, however, have no such affinity for the color, and therefore processes must be adopted for fixing the dye upon cotton and linen fabrics. One of these processes is to prepare the fabric with some animal substance, as albumen, serum of blood, the caseine of milk, or the gluten of wheaten flour. Advantage is also taken of the power which tannin has of combining with the color and rendering it insoluble. The process of Messrs. Puller and Perkin is to soak the cotton tissue in a decoction of sumach, or other tannin material, for an hour or two, and then in a solution of stannate of soda for another hour; after which it is dipped into dilute sulphuric acid, and is then ready for the dye. By these contrivances the aniline colors are made fast upon all kinds of vegetable fabrics.

Starch appears to have the power of fixing the colors, for if shaken with weak solutions of them, it will absorb the color, and, by falling to the bottom of the liquid, leave the solution colorless.

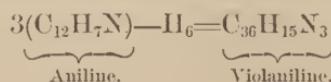
THEORY OF THE FORMATION OF COLORS.

The rationale of the change which takes place during the formation of the several colors is not altogether clear, although there can be no doubt that the essential part of it is the oxidation of aniline; for, as I have already stated, when a salt of aniline is exposed to the action of nascent oxygen set free from the positive pole of a galvanic battery, the characteristic tints of aniline are successively and quickly produced. At first there is bright yellow, then green, blue, violet, and lastly red, as if these were the successive phases of oxidation. The researches of Dr. Hofmann have demonstrated that all the aniline reds are salts of a well-defined base, which he has named rosaniline; and the more recent inquiries of MM. de Laire, Girard, and Chapoteaut have shown that there are four such bases entering into the composition of coal-tar colors, as violaniline, mauvaniline, rosaniline, and chrysotoluidine, which form an arithmetical series advancing by successive additions of C_2H_2 , thus:

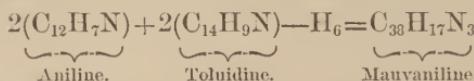
Violaniline	$C_{36}H_{15}N_3$
Mauvaniline	$C_{38}H_{17}N_3$
Rosaniline	$C_{40}H_{19}N_3$
Chrysotoluidine	$C_{42}H_{21}N_3$

Each of these bodies is produced in the same manner, by the oxidation and removal of six atoms of hydrogen from three atoms of aniline, or three atoms of toluidine, or three atoms of the mixed bases, thus:

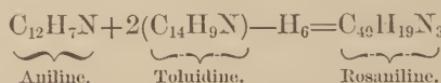
Six atoms of hydrogen from three atoms of aniline produce violaniline.



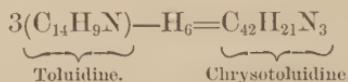
Six atoms of hydrogen from two atoms of aniline and one of toluidine produce mauvaniline.



Six atoms of hydrogen from one atom of aniline and two of toluidine produce rosaniline.



And six atoms of hydrogen from three atoms of toluidine produce chrysotoluidine.

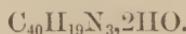


These color bases are perfectly homologous in all respects, for they not only unite with acids to form salts which crystallize very freely, and which have remarkable tinctorial power, but they also contain within them three atoms of typic hydrogen, which may be replaced by certain radicals, as of the alcohols, &c.—methyl, ethyl, phenyl, &c.—forming derivative compounds of like basic properties, and frequently of high tinctorial quality.

The best known of these bases is rosaniline, which in its anhydrous condition is represented by the formula



but which always contains two atoms of water in the hydrated state in which it is set free from its compounds, thus:



It is readily obtained by decomposing its salts—the aniline reds—with an excess of alkali, soda, or ammonia, and in this state it falls as a dirty yellow or brownish-yellow precipitate; but by careful purification it occurs as a colorless base, which quickly becomes rose-red on exposure to any acid, even the carbonic acid of the atmosphere. It is nearly insoluble in water, slightly so in ammonia, and very soluble in alcohol, forming a deep red solution. Ether and coal-tar naphtha have no solvent action upon it. It combines with one, two, or three equivalents of acid to form salts which crystallize very readily, the first of them, the mono-acid salts, being remarkable for their lustrous metallic or bronze-

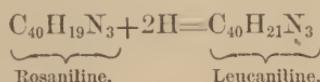
like appearance and their beautiful rose-red solutions; these, indeed, are the true coloring compounds, the most important of which are the following:

Fuchsine, or muriate of rosaniline.....	$C_{40}H_{19}N_3 \cdot HCl$
Azaleine or Magenta, the nitrate.....	$C_{40}H_{19}N_3 \cdot HNO_6$
Roseine, the acetate.....	$C_{40}H_{19}N_3 \cdot HC_4H_3O_4$

It was the last-named salt which composed the splendid bronze-like crystals of the crowns which were exhibited in 1862 by Mr. Nicholson. And, besides these, there are sulphate, arseniate, oxalate, chromate, tannate, &c., of rosaniline. Most of them are freely soluble in water and in spirit, but the tannate is so insoluble in water that it is used for fixing the color upon calico, and for recovering the dye from very weak solutions. To this end the otherwise waste products of aniline red are treated with a fresh infusion of nut-galls, and in a short time the rosaniline is precipitated in the form of a magnificent red lake of tannate of rosaniline, leaving the solution quite colorless. This lake is soluble in spirit and in acetic acid, and may be thus used for dyeing.

The salts of rosaniline with two equivalents of acid have not been studied, and even those with three of acid are not of any technical value.

Under the influence of reducing agents, as sulphide of ammonium, or the nascent hydrogen evolved from zinc when a solution of rosaniline in muriatic acid is left in contact with the metal, it is rapidly decolorized, and is transformed into a new base, which Dr. Hofmann has named leucaniline. This is effected by the absorption of two atoms of hydrogen, thus:



The new base occurs in the form of colorless acicular crystals, which are scarcely at all soluble in water, but freely so in alcohol. The salts of it are also colorless, or dazzling white, although they reacquire the red tint of rosaniline when their solutions are exposed to the action of oxidizing agents or even to the air.

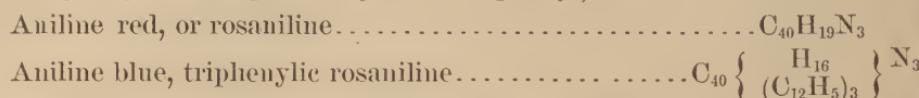
Dr. Hofmann has ascertained that there is still another base derivable from, or closely related to, rosaniline—viz: chrysaniline. It is procured from the residual, or waste product of rosaniline, by the action of steam and nitric acid, as I have already described. It contains two atoms less of hydrogen than rosaniline, and therefore it stands in its relation to this base as rosaniline does to leucaniline, thus:

Chrysaniline.....	$C_{40}H_{17}N_3$
Rosaniline.....	$C_{40}H_{19}N_3$
Leucaniline.....	$C_{40}H_{21}N_3$

It is very soluble in water, and it forms yellow salts with acids, one of which, the nitrate, is a very soluble compound. The solutions of the

base and of its salts communicate a splendid golden yellow color to animal tissues.

Aniline blues are, for the most part, substitution compounds of aniline red, the three atoms of typic hydrogen being replaced by three of an organic radical. The blue, for example, which is produced by the action of aniline on a salt of rosaniline, is a compound in which the three atoms of hydrogen are replaced by three of phenyl, thus:



And its production when aniline is heated with a salt of rosaniline is accompanied with the evolution of ammonia, disregarding the acid of the compound, thus :



Other substitution compounds, in which the three atoms of hydrogen are replaced by three of methyl, ethyl, amyl, &c., have been produced by Dr. Hofmann by the action of the iodides of these radicals on the salts of rosaniline, or even by the more simple and direct process of heating them with the alcohols of the radicals under pressure. All these compounds are basic in their character, and they mostly form, with one equivalent of an acid, the blue colors which are known as Hofmann's blue and violet, and the violet of Paris.

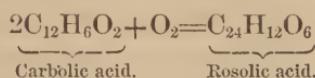
The other bases of aniline and toluidine colors have not been so well studied, but it is very probable that the reactions and the general properties of violaniline, manvaniline, and chrysotoluidine, are very similar to the preceding, and that they are capable of forming the like reduction and substitution bases.

CARBOLIC ACID COLORS.

Four or five dyes have already been produced from this compound, namely, rosolic acid or aurine, peonine or coralline, azuline, and picric acid.

Rosolic acid is contained in coal-tar, as was first demonstrated by Runge in 1834, who extracted it from the dark red-brown residual product of carbolic acid by means of spirit; and on treating the solution with caustic lime, he separated a brown compound, (brunolate of lime,) and obtained a red solution, (rosolate of lime,) from which he precipitated the rosolic acid as a dark red powder by the aid of acetic acid. Other observers, as M. Tschelnitz in 1857, and Dr. Hugo Müller still later, noticed that the common carbolate of lime of commerce became red on exposure to the air, and that this was due to the formation of rosolate and brunolate of lime; but we are indebted to Dr. Angus Smith, and more recently to M. Jourdan, for an explanation of the changes which thus take place in carbolate of lime, and for suggestions for a process for making the dye on a commercial scale. They found that when the

vapor of carbolic acid is passed over a hot mixture of soda and peroxide of manganese, or peroxide of mercury, oxygen is absorbed and rosolic acid produced, thus :



The residue yields to water a rich solution of rosolate of soda, from which the rosolic acid can be obtained by precipitating by means of acetic acid.

The production of acid commercially has been accomplished and patented by Messrs. Guinon, Marnas, and Bonnet. They mix together about 23 parts, by weight, of carbolic acid, 10 to 20 of oxalic acid, and from 7 to 14 of commercial sulphuric acid, and heat them for three hours or until the desired color is obtained. The product is well washed with water to remove the excess of acid, and the residue, which is impure rosolic acid (aurine,) is a soft pitchy material with a green shade of cautharides; but as the acid is insoluble in water and cannot well be fixed upon fabrics, the patentees have converted it into a new compound, named peonine, by incorporating nitrogen with it.

Peonine or coralline is produced by heating one part of the rosolic acid with two parts of ammonia of commerce, for three hours, in a closed metallic vessel at a temperature of 270° F. The product is a thick liquid of considerable tinctorial power, and which gives with acids a deep red insoluble or fast color, which may be so applied to silk, wool, and other textile fabrics.

Azuline, as I have already stated, is a blue color, produced by heating five parts of peonine with six or eight of aniline, and keeping them at nearly the boiling point for several hours.

Picric acid, or carbazotic acid, or trinitrophenic acid, is obtained by oxidizing carbolic acid with nitric acid. It was formerly procured by a like treatment of indigo and the yellow resin (Xanthorrhœa hastilis) of Australia, and also by the action of nitric acid upon the coal naphtha which distils between 300° and 400° F.

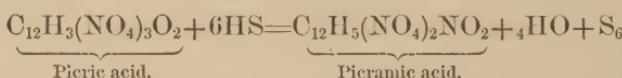
When carbolic acid is cautiously dropped into strong nitric acid it is attacked with great violence and with a hissing noise, as you may observe; and, according to the strength of the acid, there are produced one or more of the following substitution compounds :

Carbolic acid	$\text{C}_{12}\text{H}_6\text{O}_2$
Mononitrophenic acid	$\text{C}_{12}\text{H}_5\text{NO}_4\text{O}_2$
Binitrophenic acid	$\text{C}_{12}\text{H}_4(\text{NO}_4)_2\text{O}_2$
Trinitrophenic acid	$\text{C}_{12}\text{H}_3(\text{NO}_4)_3\text{O}_2$

If the acid be strong enough the last compound is alone produced, and when the mixture cools it deposits crystals of picric acid. These are purified by dissolving them in water, neutralizing the solution with carbonate of soda, evaporating, and crystallizing. The crystals of the soda salt yield, when they are decomposed with dilute sulphuric acid, fine

yellow, pearly-looking crystals, or plates of pieric acid. They are soluble in from eighty to ninety parts of cold water, and they possess considerable tinctorial power—a grain of acid in 300,000 grains of water will give a moderate shade of yellow to 1,000 grains of silk. The color is best applied with a mordant of alum and cream of tartar; cotton fabrics do not retain the color, and hence it becomes a test for such tissues when mixed with wool or silk. The solution is very bitter, and, as it is not a poisonous compound, it has been thought that it might be used instead of hops for beer. It forms yellow salts with the alkalies, and with metallic oxides, and most of them are highly fulminating or explosive when heated.

If pieric acid is submitted to the action of reducing agents it produces red colors of great beauty; thus pieramic acid is formed when the acid is reduced by means of a hot solution of protosulphate of iron, (Wöhler,) or by the aid of sulphuretted hydrogen or sulphide of ammonium, (Girard.)



The acid thus obtained is in the form of brilliant ruby-red crystals, which are soluble in alcohol and ether, and slightly soluble in water.

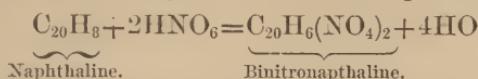
Isopurpuric acid is another red product of pieric acid. It is procured from it by the process of M. Hlasiwetz, which consists in dissolving two parts of cyanide of potassium in four of water, and when it is heated to a temperature of 140° F., adding little by little a solution of one part of pieric acid in nine of water. The liquid evolves ammonia and prussic acid, and, on cooling, deposits an abundant crop of crystals. These are washed with a little cold water, and then dissolved in boiling water to which a little carbonate of soda has been added; as the solution cools it yields tolerably pure crystals of isopurpurate of potash. They have a red-brown color by transmitted light, and a green metallic by reflected. By substituting ammonia for potash, as by dissolving the crystals in boiling water and adding sal ammoniac, there are formed, as the solution cools, beautiful red crystals of isopurpurate of ammonia, which is isomeric with the brilliant red dye called murexide, and which, but for the cheaper forms of aniline colors, would have been an important dye; for it gives to silk and wool, when mordanted with corrosive sublimate, a magnificent purple rivalling the purple of Tyre; and with a mordant of zinc it produces a brilliant yellow. The colors are very fast, but they will not resist the action of the sulphurous acid so constantly found in the atmosphere of towns.

We know but little of the homologues of carbolic acid—namely, creyslic acid ($\text{C}_{14}\text{H}_8\text{O}_2$)—and the higher members of the series, which may, perhaps, be capable of yielding corresponding colored compounds.

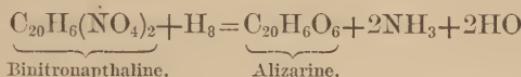
NAPHTHALINE COLORS

have not yet been successfully produced, although many attempts have been made to utilize it in this way; indeed, as far back as 1858, Strecker

drew attention to the similitude of chloroxynaphthalic acid and the red coloring constituent of madder, (alizarine,) there being required only the substitution of hydrogen for the chlorine to change it into madder red; and in 1861, M. Z. Roussin announced that he had actually converted naphthaline into alizarine. His process was first to act on naphthaline with nitric acid, and so change it into binitronaphthaline, thus:



This is a crystalline body, which he next dissolved, little by little, in concentrated sulphuric acid. The mixture was then heated to a temperature of 392° F., and small portions of granulated zinc were cautiously added to it. After a time sulphurous acid began to be evolved, and the nitronaphthaline was slowly converted into a red coloring matter, which he thought was alizarine. The change appeared to be as follows:



By diluting the mixture with eight or ten times its bulk of boiling water, and quickly filtering, the solution yielded as it cooled brilliant red crystals. But they differ from alizarine in many essential particulars, especially in not giving the purple and chocolate tints, as alizarine does, with iron and alumina mordants.

Mr. Perkin has also devoted attention to this subject, but his labors have not been very successful.

Naphthalamine is a compound which bears the same relation to naphthaline that aniline does to benzole, and it is made by somewhat similar transformations. Messrs. Calvert, of the Tower Chemical Works, have produced it very largely, in the hope that, by oxidation in the same way as aniline and toluidine are oxidized, colors might be obtained. In this manner Mr. Brunner produced in Mr. Calvert's laboratory a very fine purple by heating it with arsenic acid. M. Du Wildes obtained a like result with the nitrates of mercury; and M. Roussin has shown how fabrics may be dyed of a red color by acting on muriate of naphthalamine with nitrite of potash, and how a violet red tint may be obtained by heating a mixture of naphthalamine and dry bichloride of mercury in a sealed tube, at a temperature of 350° , for many hours, and by heating a mixture of muriate of naphthalamine and protochloride of tin to a temperature of 472° F. The purple red color is in both cases insoluble in water, but soluble in alcohol, and may be thus used as a dye. Messrs. Guinon, Marnas, and Bonnet have also proposed to use it in the place of aniline for the production of a blue color; but I am not aware that any of these processes have been put into actual practice.

CHAPTER VIII.

STEARIC ACID INDUSTRY.

STEARINE—MANUFACTURE OF CANDLES—IMPORTANCE OF THE STEARIC ACID INDUSTRY—HISTORICAL NOTICE—THE DE MILLY AND MOTARD PROCESS OF SAPONIFICATION—SUCCESSFUL MANUFACTURE OF STAR CANDLES—SAPONIFICATION BY SULPHURIC ACID—SAPONIFICATION BY WATER AND DISTILLATION—SAPONIFICATION BY WATER UNDER HIGH PRESSURE—THE CHANGE OF FATS UNDER PRESSURE, WITH HEAT—TILGHMANN'S PROCESS—DE MILLY'S BOILER OR AUTOCLAVE FOR DECOMPOSING FATS—SAPONIFICATION BY SULPHURIC ACID WITHOUT DISTILLATION—MACHINERY FOR THE MANUFACTURE OF CANDLES—OLEIC ACID—QUALITY OF CANDLES—SOAP—CONCLUSION.

STEARINE.

MANUFACTURE OF CANDLES.

The name stearine does not represent the true character of the substance, (it being stearic acid,) but as it is one accepted by the industrial world, it is proper to retain it. This substance, the result of certain chemical processes, is now manufactured in all parts of the world, and specimens in block and in the form of candles are to be found in Class 44 of almost every country represented at the Exposition. The quality of the product does not vary materially. There seems to be rather a greater range in the qualities manufactured in some countries than in those manufactured in others. In France the demand for quality appears more uniform than in England, for in England a large number of softer candles are in general use, while the universal demand in France is for a hard, white, smooth candle. The principal difference noticed in candle stuffs at the Exposition is that some are a little more mottled than others. This is attributable in part to the difference of the methods of saponification—that made by the sulphuric acid saponification being more mottled than when treated by lime; but my observation convinces me that this defect is principally due to the method and care in cooling the melted stearine before molding. In the character of the stearine products, there is no advance on the Exposition in London in 1862, this being due to the fact that there was hardly anything left to be desired under this head.

If we are enabled to make such beautiful candles out of almost any description of fatty matter, it is entirely due to the application of some of the most interesting chemical results on record; and it is with just pride that France can claim the development of the whole subject from its incipiency to the present perfection of the industrial processes. These labors commenced with M. Bracomot, of Nancy, in separating oleine and

stearine, and were extended through the remarkable scientific researches of M. Chevreul. That these labors deserve to be ranked so high, arises from the fact that they were made at the birth of organic chemistry and on a most difficult class of bodies, about the nature of which there was no correct conception and when the analyses of organic substances had been but just commenced. Still more, M. Chevreul did not give to the world the results of his labors as a mass of isolated facts, but he systematized and classified new acids, new bases, and left to us the chemical history of facts almost as fully made out as they are at the present time; and these have contributed as much if not more than any class of researches to give direction and growth to organic chemistry. The decomposition of the fats and formation of the fatty acids developed the fact that when melted and allowed to cool slowly the more solid acids crystallized out of the mixed mass in such manner as to allow of easy separation of the solid from the liquid part, which fact soon suggested a practical application. Without, however, going into details of all the known processes, so fully and clearly described by M. Strass in the report of the Exposition of 1855, a tolerably comprehensive review of the subject will be given.

In 1823 a complete account of the labors of Chevreul was published; at this period fruitless efforts were made to manufacture stearine, but without success. It was in 1831 that Adolph de Milly overcame the practical difficulties of manufacturing stearine on a large scale, and established this branch of industry on certain principles, some of which have remained unaltered, while others have been materially changed in later years by the same chemist, as will be seen a little further on.

The first countries in which stearine candles were manufactured were France, England, Belgium, Russia, Austria, and Sweden. This manufacture gradually found its way into other parts of the world, and it is now carried on in the remotest places, as Calcutta and Sidney, (Australia.)

IMPORTANCE OF THE STEARIC ACID INDUSTRY.

It is difficult to render an exact account of the importance of the stearic acid industry; nevertheless it can be stated with certainty that the annual production for France is 25,000,000 of kilograms, and approximately for the remainder of Europe is 100,000,000 of kilograms, and for America 10,000,000 of kilograms.

The largest candle factory in the world is that known as the Price Company, having its principal establishments at Liverpool and London, with a capital of 5,000,000 of dollars. Its principal products are what are called the composition candles, of a good quality, but a little greasy to the touch. These candles are used in England by all classes, but would not be received in other countries, where the requirements of luxury are more exacting. The establishments in Holland and Belgium are relatively of great importance, arising from the fact that apparatus, coal, and labor are cheap; the consequence being that these candles are manufactured

cheaply and sold at corresponding prices, and are enabled to be exported more than they are used. As previously stated, from 1831 to 1846, saponification in open vessels by lime was altogether employed; in 1846 another process was introduced, viz: saponification by sulphuric acid followed by distillation. These two processes had their advantages and disadvantages. The saponification by lime gave a small relative yield of candle stuff, but the candles were of the finest quality, having a high melting point; the yield of oleic acid was greater and of a superior quality. On the contrary, the sulphuric acid followed by distillation yielded a larger amount of candle stuff, but of second quality, and a smaller yield of liquid matter of inferior quality. The industrial world employs one or other of these methods, according to the requirements and circumstances governing the demand and the nature of raw material employed. In some countries smooth, white, dry candles of a light melting point and of the first quality are required, while in other countries, attracted by the low price, a candle is used that is yellowish, soft, and greasy to the touch, with a low fusing point. For this reason, France, Germany, Russia, Italy, Spain, and Portugal still employ the lime saponification, and Belgium, Holland, England, and America adopt the sulphuric acid to a great extent. As regards the profits of the two methods they are about balanced, because one class of manufacturers sell at a higher price for products of a better quality but smaller yield, while the other class sell an article at a lower price but of an inferior quality. But it is an observed fact that those who manufacture by sulphuric acid and distillation do not meet with the same commercial success as those manufacturing by lime.

There were forty or fifty factories that exposed products arising from the treatment of fats. Of these about thirty were French. Nineteen of these employed the old lime saponification with fourteen per cent. of lime; three by the closed autoclave under pressure with a diminished quantity of lime; one by the sulphuric acid saponification; two by water decomposition under pressure, and five by different methods of distillation. The more modern method of saponifying under pressure is gradually coming into use, and Messrs. Perré & Son, of Elbeuf, exhibited beautiful products made by that process with the apparatus invented by Renner.

ACCOUNT OF THE STEARINE INDUSTRY.

The first persons who thought of applying the fatty acids for the purposes of illumination were Gay Lussac and Chevreul. For this purpose they took out a patent in January, 1825, which patent specified "that they reserved to themselves the exclusive right of preparing fatty acids for illumination, both liquid and solid, such as are obtained by saponification of the fats with *potash, soda, and the other bases, by the acids or by any other means.*

"We saponify the fats either at the ordinary boiling point with the pressure of a single atmosphere, or at a more elevated temperature with

the pressure of several atmospheres. We have recognized that the saponification conducted in this way has great advantages over that conducted in the ordinary way under a single atmospheric pressure, 'the saponification being accomplished with the smallest possible quantity of alkali. We separate the stearic and margaric acid from oleic acid by the following processes:'''

This is done by several processes detailed in the patent, but the one essentially practical is by decomposing the soap with acids, and, by pressure, separating the solid from the liquid acids. It will be seen that this process is deduced directly from the theoretical researches of Chevreul, with the important exception in relation to saponifying under high pressure.

The process of Chevreul and Gay Lussac was not considered at the time capable of being brought into practice in the arts, from their using potash and soda, thus making the product a very expensive one.

Besides the above difficulty in the original development of stearic industry, another arose in the very commencement, viz.; that when candles were made with the ordinary wick they burnt very imperfectly, and the inventors above referred to devised wicks of peculiar description that answered the purpose more or less perfectly. But prior to them, J. L. Cambacérés devised similar ones, and subsequently improved upon them, and finally settled upon the plaited wick now in common use in all stearic acid factories.

The next important step in rendering the stearic acid industry a success was also made by M. Cambacérés, viz: the separation of the oleic acid by powerful pressure, first on the mixed acids cold, and subsequently warmed; and he established a factory in Paris to carry out his process, but this soon failed, from the inferior nature of candle-stock produced and the expense of its production, potash being employed by him as the agent for decomposing the fats.

For several years this industry was abandoned as being a difficult and unprofitable one, when, in 1829, two young physicians, De Milly and Motard, took the subject up, and, after two years of laborious and persistent study of it, accomplished the problem of the successful manufacture of candles from the fatty acids. It is only simple justice to say that the names of Chevreul and De Milly go side by side in this industry, the first in his theoretical discoveries, and the latter in his ingenious and successful devices in the accomplishment of great practical results. Nor is it too much to rank De Milly nearly as high as Leblanc for endowing chemical industry with an art so thoroughly perfected by him and leading to such important economical results in the every-day wants of the civilized world. France may well be proud of having given to the world the art of making soda by Leblanc, and that of making stearic acid candles by De Milly.

The success in making these candles depended first on the discovery of an economical means of saponification. This means consisted in the

employment of lime to replace potash or soda, which method had been indicated in the original patent of Gay Lussac, but no one had solved the problem successfully until it was done by MM. De Milly and Motard, in 1831, in a factory established by them near the *Barriere de l'Etoile* at Paris, and it is from the locality of this first factory that the almost universal name of "star candles" has been derived.

In the original method of saponifying by lime, De Milly and Motard conducted the operation in a closed vessel, under pressure, but from the difficulty of proper manipulation during the operation, it was abandoned, and afterwards carried on in an open vessel at the temperature of 100° C. We do not intend to go into any detail as regards the process already so well known and described in works on technical chemistry, but simply to give a rapid sketch of its history and development.

THE DE MILLY AND MOTARD PROCESS OF SAPONIFICATION.

After the lime soap is formed, it is decomposed by sulphuric acid, and the resulting fatty acids are cooled in shallow tin or copper pans, in rooms of about 60° F., so as to allow of the proper crystallization of the solid acids. The next step is to press these acid cakes, which is first done in a cold press, then in a hot press, first suggested by Cambacérés, but successfully carried out by the horizontal presses invented by De Milly and Motard, and now universally employed in candle factories.

The difficulties, however, of these indefatigable manufacturers were far from being overcome; the pans colored the fats with iron, the last trace of lime was not removed, and the candle made had a crystalline structure. By the alternate application of steam and dilute sulphuric acid, and white of egg and oxalic acid, they overcame the first difficulty. Various means were tried to prevent the crystalline structure, commencing with the objectionable use of arsenious acid, then the more expensive one of wax, which also had a tendency to color the candle; they at last triumphed over this difficulty by cooling the acids to a temperature near their point of solidification before introducing them into the molds that were first raised to the temperature of the cooling fats. During the cooling of the mass it is constantly agitated, and a pasty liquid is produced, which congeals in the molds without crystallization. Three years had now elapsed since the first establishment of their factory, the commercial results of which had been a failure. M. De Milly now came into the possession of the factory alone, his faith in its success remaining firm, and two years later, in June, 1836, he gave the perfecting touch to the successful manufacture of *star candles*. The wick has always been a source of great annoyance in the burning of the candles, for the small amount of mineral matter in the candle stuff would accumulate in the wick, and interfere with the free flowing of the melted fat. After numerous trials by saturating the wick with different substances, the required result was successfully accomplished by impregnating the wick with a certain quantity of boracic acid, dissolved in water, containing

one-thousandth of its weight of sulphuric acid. The boracic acid, as the combustion of the candle progressed, united with the lime and the ashes of the wick, forming a very fusible salt, which accumulated on the end of the wick, forming a small drop.

With this last application in 1836 is to be dated the complete success of the stearic acid industry. The civilized world recognized it as such, and factories sprang into existence in various parts of Europe and America. Since then there have been some minor perfections in the above process, known as the *lime saponification process*. There have been, however, other processes put in practice for bringing about the same results that will be passed in review, viz.:

- 1st. Saponification by sulphuric acid and subsequent distillation.
- 2d. Saponification by water combined with distillation or glycerine and fatty acids.
- 3d. Saponification by water under pressure.
- 4th. Saponification by water under pressure with a very minute quantity of lime.
- 5th. Saponification by sulphuric acid without subsequent distillation.

SULPHURIC ACID SAPONIFICATION.

This method was discovered by Chevreul in his original researches on fatty bodies, and in the patent taken out by him in conjunction with Gay Lussac in 1825, this method is specified, but certain portions of the fats were so altered as to discolor the product to such an extent as to render it of no use in practice. The acids, however, thus formed, could be distilled more or less perfectly, as first shown by Chevreul, and subsequently practically executed by Dubrunfaut. But the first idea of combining the two operations, viz: sulphuric acid saponification followed by distillation, is due to Coley Jones and Wilson, of England, subsequently perfected by Gwinne and Jones.

The process as it is now carried out may be summed up as follows: The fat is placed in large vessels that may be of wood or masonry lined with lead, and from six to fifteen per cent. of concentrated sulphuric acid is added; the mixture is then heated by a steam coil to near the temperature of boiling water, and maintained at that temperature eighteen or twenty hours. Some, however, operate at a higher temperature, and consume less time in the reaction, with as much as thirty per cent. of sulphuric acid and agitation, decomposing batches of two hundred pounds in four minutes. The fat is decomposed with an alteration of part of the glycerine and part of the fat, sulphurous acid and carbonic acid being evolved. The black mass resulting from the action of the sulphuric acid is now thoroughly washed by boiling water, until all the fatty acids are freed completely from sulphuric acid. The fatty acids are now introduced into large cast-iron stills, capable of holding over one ton of these acids. The stills are heated

from below, so as to bring the contents to the temperature of 260° C., when a jet of superheated steam of 350° to 380° C. is made to traverse the charge, and in about twelve hours the matter is distilled over, leaving behind a pitchy substance, which may be used in the manufacture of gas, or for coating roofs and other purposes in the arts. The fatty acids when distilled may be cooled in pans, and submitted to the cold and hot pressure; for some purposes it is submitted only to the cold pressure, and in England much is used without any pressure at all, when palm oil has been the fat acted upon.

This method contrasted with the lime saponification has its advantages and disadvantages; among its advantages are the facility of using common and refuse fats, and in giving a larger yield of candle stuff; among its disadvantages are the inferior grade of candle stock produced, and the actual loss of about ten per cent. of the fat by decomposition into gaseous and pitchy matters.

The comparative yield of lime and sulphuric acid saponifications in candle stock from tallow and palm oil is forty-seven per cent. for the lime, and sixty-two per cent. for the sulphuric acid.

SAPONIFICATION BY WATER AND DISTILLATION.

The decomposition of fats by the increase of temperature and the subsequent distillation of the fat acids was originally observed by Chevreuil, and different methods were devised by Moses Poole and by Gay Lussac, as early as 1828, to obtain practical results from it, but so much acroleine was formed that it was abandoned as impracticable. Dubrunfaut revived the method, and was more successful; but it was reserved for George Wilson, of the Price Candle Works, near London, to solve the problem in 1852, at least so far as palm oil was concerned; and 1855 he had three stills in operation, each of a capacity of about 1,600 gallons; from which, by one and the same operation the fat acids and glycerine were distilled over uncombined.

To accomplish this two-fold result, viz: to accomplish the watery saponification of the neutral fats, and the distillation of the fatty acids and the glycerine that result from the saponification, it is necessary to heat the fat in a still to a temperature between 290° and 315° C., and to pass through the heated fat a current of superheated steam, properly subdivided, having a temperature of 315° C. For proper success in the operation, the distillation must be conducted between 290° and 315° C., as otherwise the distillation is very slow, or acroleine is produced. This distillation goes on slower than when the fatty acids already formed are acted upon, the latter being accomplished in one-half or one-third the time. The glycerine distilled is of a good quality, and admits of further purification, thus forming the widely known and much appreciated *Price's glycerine*. It is well to state here that the employment of other than palm oil in this process gives unsatisfactory results, and consequently its use is limited.

SAPONIFICATION BY WATER UNDER HIGH PRESSURE.

The conception of this method, in common with all the methods of saponification of fatty bodies, is to be referred back to the author of the discovery of the true nature of fats, M. Chevreul, for in his original researches he pointed out the perfect analogy between the fats and the compound ethers, the latter class of bodies being decomposed with their two constituents in the presence of water heated in close vessels under pressure; a reasonable deduction from which was that fats would undergo an analogous decomposition. This, however, was not undertaken at the time, but, by an accident about the time of Chevreul's researches, it was first observed to take place by Faraday when his attention was drawn to some changes in oils used by Perkins in his curious steam-engine that employed very hot water. Faraday records the facts as observed by him in the Quarterly Journal of Science, Literature, and the Arts, published in London in 1823, vol. xvi, page 172, as follows:

*"Change of fats in Perkins's engine by water, heat, and pressure.—*Mr. Perkins uses in his steam cylinder a mixture of about equal parts of Russia tallow and olive oil to lubricate the piston and diminish friction. This mixture is consequently exposed to the action of steam at considerable pressure and temperature; being carried in by the steam it is found in the water, giving rise to peculiar appearances.

"The original mixture is solid at common temperature, but fuses at about 85° F. When boiled in alcohol a small portion dissolves. The water as it issues from the end of the ejection pipe into the tub placed to receive it and from which it is pumped up again into the generator, appears white and translucent, after having been used, sometimes resembles, very much, thin milk. A scum is found floating on it which, when collected together, forms a solid mass, but when it has been long exposed to the action of steam, and at a high temperature, it has very nearly the consistency of wax. It is always black and dirty.

"A portion of this substance was digested in hot alcohol and the clear solution set aside; floeuli separated in abundance from it in cooling, which, when dried and collected and fused, gave a grayish substance, contracting and cracking as it cooled, with the luster and appearance of wax, but rather more brittle. It does not melt in boiling water, but at a higher temperature melts and ultimately burns like wax. It is rather lighter than water; it dissolves readily in alkalies, more readily, I think, than fat, and in this respect *resembles Chevreul's acids of fats* as well as in its solubility in alcohol. The alkaline solution is turbid. It is not soluble in ether, or very slightly so; when burnt, it leaves an ash consisting principally of carbonate of lime. The cold alcoholic solution on evaporation left a substance similar in many respects, but much softer, even fluid. It burnt in the same manner, leaving a slight ash of carbonate of lime."

The above is sufficient to show that the practical decomposition of

fats by water heated under pressure was accomplished as far back as 1823, as any chemist will conclude from Faraday's observation made at a time when we were much less endowed with facilities for research than we are now. No attempt was then made to draw any practical results from these observations, and we find no further notice taken of the subject until early in the year 1854, by R. A. Tilghmann, of Philadelphia, when patents were taken out by him for decomposing fats mixed with water and superheated in vessels of a certain description, the sum and substance of which method is embraced in the following portion of the specifications.

TILGHMANN'S PROCESS.

He mixes the fat on which he operates with one-third or one-half its volume of water and the mixture is placed in some convenient vessel in which it can be submitted to heat equal to that of melted lead, and kept at that temperature until the operation is complete. The vessel is to be closed so that the requisite pressure can be applied to prevent the water from being converted into steam. The result of the action is the splitting of the fat into fatty acids and glycerine, which can be readily separated, mechanically, and both prepared for market. The acids are cooled in the ordinary way and submitted to pressure to procure candle stuff.

The method of Tilghmann, as originally patented, was never introduced into practice; since then, with change in the manner of operating and in the nature of the boilers, it has been successfully conducted in many factories.

In the latter part of the same year that Tilghmann's process was patented, M. Melsens, of Belgium, took out a patent very analogous, using fats mixed with water in the proportion of twenty to one hundred per cent. of the latter; the water might be acidulated with from one to ten per cent. of sulphuric acid, or the addition of salt would suffice; the whole was heated from 180° to 200° C. for several hours. The success of Melsens process was immediate, and it was put into operation on a large scale in Antwerp in vessels holding one ton of tallow, to which was added fifty per cent. of water, and in six hours the decomposition was complete at a temperature of 180° C. (ten atmospheres.) The fatty acids thus made were of a very satisfactory quality, quite as much so as those obtained by other methods of saponification.

DE MILLY'S PROCESS OF DECOMPOSING BY WATER UNDER PRESSURE, WITH A MINUTE QUANTITY OF LIME.

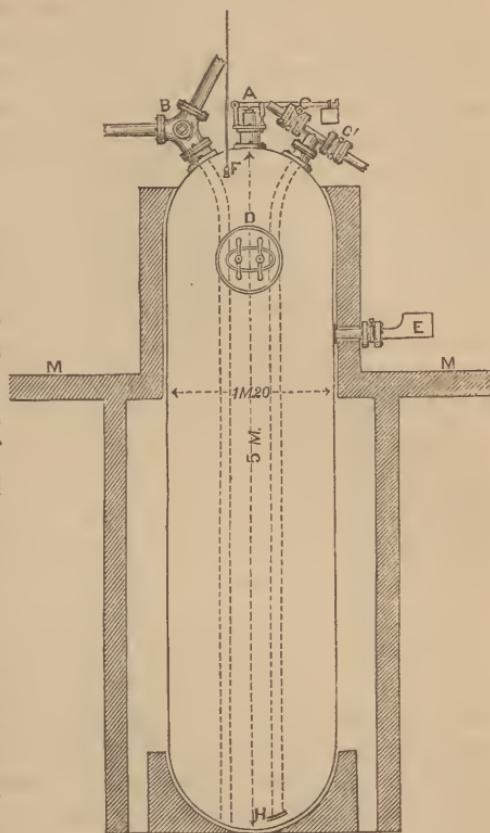
In 1854 De Milly made an important improvement in the stearic acid industry, by heating the fats at a high temperature with a small quantity of lime, much less than is necessary to saponify the fats in open vessels. This method is much more practicable and rapid than that by water alone, and is consequently extensively used, accomplishing almost every-

thing that can be desired in this respect. The construction of the boiler employed by M. De Milly is given from a drawing made from that which he employs in his factory, and it is so simple that it can be understood at once by inspection.

A, safety-valve with lever and weights; B, the screw-valve for emptying the vessel; C C', cocks for introducing the steam; D, man-holes; E, funnel and cock for introducing the materials; F, cock and tube to the pressure gauge above, not shown; H, a moveable plate of copper that acts as an agitator as the steam strikes it on entering, and at the same time protects the bottom of the vessel from the mechanical action of the jet of steam. The cylindrical vessel is made of copper 15 millimeters thick, 5 meters long, and 1.20 meters in diameter. The ends are rounded, and it is set in masonry, M; the lower portion being dropped below the floor of the factory. The details of the process as carried on with this boiler are as follows: Introduce in the autoclave the fats to be saponified, and a

quantity of water equal to that of the fats less the quantity required for making the milk of lime. For the autoclave used by De Milly, (of copper,) the dimensions of which are given in the figure, 2,000 kilograms of fat are employed. The mixture is brought to the boiling point, the milk of lime being prepared with the water that has been retained having added to it from two to four per cent. of lime. This lime mixture is now introduced by degrees into the autoclave, and in such manner as not to arrest the ebullition, so as to obtain an intimate mixture of the fat and lime, forming a kind of emulsion. Everything being thus arranged, the safety-valve is closed, which, however, allows an escape of a small amount of steam, causing a continuous movement in the mass. The steam being let on from a boiler having the proper heat and pressure, the temperature is gradually elevated to a pressure of eight atmospheres, or about 345° F. At this point the flow of steam is arrested so as to maintain the temperature of the fat and lime at this point for four hours. The saponification may then be considered as finished, and the

Fig. 5.



De Milly's Boiler or "Autoclave" for decomposing fats under pressure.

autoclave can be emptied by the proper valves. The subsequent processes of treatment by sulphuric acid, pressure, &c., are the same as for the ordinary lime saponification.

This new method of saponification was received with much doubt, when it was announced in 1855, and but little notice was taken of it; but since that time it is sanctioned by practice, and has been introduced into nearly all the factories where saponification by lime is adhered to, realizing a considerable saving in lime, sulphuric acid, labor, and time. There is also an economy of fatty matter, for the greater the quantity of sulphate of lime that is formed the more fat gets mechanically mixed with it, and is lost. This method is extensively used in Europe and this country. It remains now to speak of a new discovery, made by M. De Milly in the commencement of the year 1866, and which is destined to exercise a considerable influence upon the stearic acid industry.

SAPONIFICATION BY SULPHURIC ACID WITHOUT DISTILLATION.

Fats saponified by sulphuric acid by the ordinary method contain more or less tarry matter, arising from the decomposition of the fats, causing more or less loss in the raw material.

M. De Milly undertook a series of experiments, by which he finally showed that fats could be saponified by sulphuric acid without the formation of tarry matter. This point being established, he further showed that the fatty acids obtained without the formation of tarry matter were identical with the fatty acids formed by the lime saponification. These he submitted to cold and hot pressure under special conditions, and obtained cakes of candle stuff most beautifully white. As to the oleic acid, it is of a dark color, but in no way decomposed; it makes a fine brown soap, or it can be distilled and made white.

M. Balard, in a report on this process, expresses himself in the following terms:

"In the establishment of M. de Milly, the fat is melted and heated to 120° C.; it is then allowed to flow from its reservoir and mix with a stream of strong sulphuric acid, in the proportion of six per cent. of the latter. The mixture is rendered perfect by means of agitation. The action takes place immediately, and is arrested in two or three minutes by allowing the mixture to flow into boiling water, when the sulphuric acid and unaltered glycerine enters into solution and the fatty acids float on the surface, being of a dark color. But, contrary to what takes place in the ordinary method of saponification by sulphuric acid, the coloring matter is completely soluble in the liquid fat acid, so that by cold and hot compression the solid fat acids are obtained perfectly white, ready to be molded into candles. The entire operation can be accomplished in one hour.

"Nevertheless, it is preferable, when the cold pressure has furnished the solid acid but still colored, to melt it again and put into the pans;

then on cooling to submit it to all necessary pressure, when a fatty acid, fusible at 55° C. is obtained, admirably adapted for the very finest candles.

"It is readily seen that a certain portion of the solid fat acid will find its way into the liquid acid, as the crystallizable sugar in molasses; this can be submitted to distillation. Here, however, the distillation, conducted in such manner, only operates on less than one-fourth of the original solid fat, as the other three-fourths have been separated before the distillation. It is evident that the method unites the advantage of lime saponification and the process of distillation. Three-fourths of the acid obtained is fit for the best quality of candles, and the other fourth for a second quality. The yield of solid fat acids by this method, when properly conducted, is greater than by the other method of saponification with sulphuric acid, there being no loss by carbonization."

This new process, which has been carried on for some time in the factory of De Milly, introduces an extreme simplicity into the stearic acid industry. All that is necessary to conduct the operation are a few receivers and two or three hydraulic presses, requiring but a small amount of capital. It is being introduced into various parts of Europe. M. De Milly has taken out a patent in this country, but as yet it has not been carried out practically. This process bids fair to take a high rank among the known processes for manufacturing candles.

MACHINERY CONNECTED WITH THE MANUFACTURE OF CANDLES.

There was nothing under this head exhibited worthy of special notice. Leon Droux showed a new form of autoclave for treating fat under pressure with water, but it appeared to the writer to be inferior to several forms now in use. Leroy & Durand exhibited a new still, in which there was nothing new except a method for regulating the temperature of the superheated steam. There was a square box inserted in the masonry acting as a recipient of two jets of steam, one highly superheated and the other from the steam boiler; both jets were regulated by valves that could be adjusted to admit more or less of one or other flows of steam, thus regulating in a very ready manner the temperature of the steam admitted to the still. Morane and others exhibited molding machinery, but there was no new improvement on the already admirable machines for accomplishing this part of the manufacture of candles.

OLEIC ACID FROM THE MANUFACTURE OF CANDLES.

The employment of this acid formed a part of the original patent of Chevreul & Gay Lussac, viz, to convert it into soap; but when the candle industry was first successfully conducted by De Milly & Motard, they found it impossible to dispose of the oleic acid to the soap makers, they being prejudiced against its use; so these manufacturers in their unconquerable perseverance converted it into soap themselves, and now a soap department is the natural adjunct to every candle factory. This acid

is also employed to replace the oil used in the manufacture of woolen cloth, an application first suggested by Peligot & Alcan. Attempts have been made to procure elaidic acid (a solid oil acid) by well-known reaction of hyponitric acid upon it, thus increasing the amount of fat which can be used in making candles; but owing to the fact that this reaction produces a red substance that becomes mixed with the fat acid, the method has never found its way into industrial chemistry, and the solution of this question is left to future chemists.

QUALITY OF CANDLES.

The following are some of the points to be noticed in forming a correct opinion of the quality of candles:

- 1st. The nature of fatty matter used in their manufacture.
- 2d. Their whiteness.
- 3d. Their transparency.
- 4th. Their hardness.
- 5th. Their dryness to the touch.
- 6th. Their point of fusion.
- 7th. Their form and their molding.
- 8th. The nature of the wick.
- 9th. The nature of the flame: if it be uniform, long or short, well supplied, illuminating, brilliant, with or without smoke.
- 10th. Does the cupping at the top of the candle burn dry, or is it more or less filled with melted fat?

11th. Is the fatty matter free from mineral substances?

The above list, as made out by Stass, gives all the points worthy of note to furnish a correct idea of the quality of candles. The point of fusion of the best quality of candles, should not fall short of 55° C. The candles from palm oil acids, although giving very excellent light, seldom exceed 51° C., and often fall short of it. To obviate the disadvantages of using the more fusible candles some manufacturers now envelop them in a layer of material that melts at 56° C. This is done in molding them; and while it is advantageous, it is only an imperfect substitute for those made altogether of harder material. The candles made from distilled material give a whiter light than those from lime saponification, but are less fusible and color more or less in contact with the air, for which reason the star candle from lime saponification ranks highest in commerce.

SOAP.

Under this head nothing new was developed, except the use of oleic acid from the new method of De Milly, of saponifying fats by sulphuric acid without subsequent distillation. The detergent property of this soap is not inferior to that of any other, although the color is very much darker. The manufacture of soap increases very rapidly, every day new factories springing into existence in all parts of the world. Mar-

seilles still ranks first in the soap industry, although the inferior fats and oils are used more than formerly. We are indebted for the present condition of this industry to M. Chevreul, as well as for that of stearine candles, which now both go hand in hand, as the candle-maker must be a soap-maker to consume the excess of oleic acid which is formed in the manufacture of candles.

The different makers try to rival each other in the manner of making up the soap for market, both in appearance and size of separate masses. For the consumers the pound lump is more and more commonly used, and nowhere is the appearance of the soap attended to with more care than at the factory of the Barrière de l'Etoile, where De Milly first engrafted soap-making on star-candle making.

CONCLUSION.

This rather lengthy report on the industrial chemistry of the Paris Exposition gives but an imperfect view of what was exhibited under this class; but it is necessary to terminate it here, and refer those desirous of more detailed information on many points to scientific and technical periodicals and reports, in which the chemical products and processes have been specially treated.

To describe the machinery, and to give statistics of separate establishments which manufacture one or more products, would extend this report into several volumes.

The gigantic nature of some of these establishments, and their operations as now conducted, may be seen in the establishment of Messrs. Castelaz & Co., of Paris. They decompose daily two tons of nitrate of soda by sulphuric acid to furnish the nitric acid they use for the purpose of producing the nitrogen compounds of benzol and toluol, for transforming arsenious into arsenic acid, phenic acid into picric acid, the bichloride of naphthaline into phthalic acid, &c. They transform daily a ton of benzol into nitro-benzol and aniline; they also make naphthaline for the purpose of producing benzoic acid, first forming phthalic acid from the bichloride of naphthaline. The phthalate of ammonia, distilled, gives phthalimide of lucine; distilled with powdered lime, the phthalimide produces benzonitrile, and benzonitrile distilled with caustic soda gives benzoate of soda, from which hydrochloric acid precipitates benzoic acid. Attacked by nitric acid, the bichloride of naphthaline leads to an oil and forms binitrated chloride, or binitro-chloroform of Berthelot, of which the odor is so penetrating and the action on the eyes and respiratory organs so terribly deleterious. A few grams are sufficient to cause the most painful burning to a thousand persons.

DESCRIPTION OF THE PLATES.

PLATE I.

GENERAL PLAN OF VITRIOL WORKS.

This plan is designed to show what is regarded as the most convenient, compact, and economical arrangement of the various buildings, store-houses, and parts of the apparatus of works for the manufacture of sulphuric acid. The space covered is about one hundred and fifty by one hundred and seventy-five feet, and the drawing is intended to be on a scale of one-sixteenth of an inch to one foot, but in reducing by photography from the original drawing it has been made slightly smaller. The lot, or ground, beyond the boundary wall, on the side opposite to the main entrance, should be owned by the establishment, and be held in reserve for other chemical purposes, or for an extension of the works, especially for another set of pyrites furnaces and chambers, as they would be conveniently close to the steamers and platinum apparatus, and could be added without disarranging the other works.

PLATE II.

ELEVATIONS AND SECTIONS IN DETAIL OF WORKS FOR MAKING SULPHURIC ACID.

This plate shows the construction of the chambers, the vent column, and the chimney, upon a scale of one-eighth of an inch to one foot. The position of the sulphur furnaces is shown, but they are not represented in detail on this plate, (see Plate IV.) A section of the "furnace column" is given, however, and its connection with the chamber is shown. The figures at the right of the chimney shaft represent the timber framing of the side and of the top of the chamber.

THE FURNACE COLUMN.

The furnace column, seen beyond the sulphur furnaces, is shown in section; this cools the gases from the furnace, and supplies them with nitrous gas and with steam, while it renitrizes the liquor from the vent column and reconverts it. It is built square, both the lead work and timber framework measuring six feet on a side; the framework is diagonally braced to give it strength; the column is lined with fire bricks closely built together, but not cemented; the brick work is built fourteen inches thick to a height of six feet above the center of the inlet

pipe; for the remaining distance above this it is only nine inches in thickness, and stands throughout the whole height two inches free within the lead work, which weighs twelve pounds to the square foot. The arch above is groined, with ample rise, as represented, and its bricks are spaced four inches, making quarter bond; their inner edges are chipped, to make the liquor drop clear from them instead of trickling down the abutments.

THE CHAMBERS.

The position of the chambers relatively to each other and to the other parts of the works is shown at the left-hand end of the plate. Chamber No. 1 is shown in section at one end of its principal studs. The figure of chamber 2 shows the framing of the end, and the manner in which it is diagonally braced to chamber No. 1. These chambers are 24 feet wide and 16 feet high inside, at one side, and $15\frac{1}{4}$ feet high at the other, the difference being due to the slope of the roof, which is 9 inches in 24 feet. The roof joists are of pine, 3 by 9 inches. There are twenty-four joists of 26 feet in length, and five of 30 feet in length. The studs of the sides and ends are 5 by $2\frac{1}{2}$ inches, and 5 by 5 inches, and the diagonal braces are 5 by 3 inches. The sleepers or sills are 4 by 9 inches. Other dimensions are given upon the plate.

In the view of the framing of the side of the chamber the studs are shown placed three feet apart from center to center. The "bays" or spaces between these studs are divided by two horizontal pieces, so placed as to divide the space into three equal parts on the highest side of the chambers, and on the lowest side, under the eaves of the roof, the top third, only, is shortened by the difference (nine inches) between the height of the two sides.

Each chamber floor is fifteen inches higher than that next below.

These chambers are supported upon brick foundations rising about eleven feet above the surface of the ground. The bricks are laid in piers about eighteen inches square, and the work is stronger and more economical if laid in half-bond, with a course of headers between every five courses of stretchers in the nine-inch work; and all the chimney bond, *i. e.*, hollow four-inch work, should be half-bond to form the piers.

THE VENT COLUMN.

This is shown in section at the side of chamber No. 1. The nitrous gas which escapes from the vent is absorbed in this column by means of sulphuric acid "brown," or eighty per cent. acid. The specific gravity of the acid used is generally 1.712, but 1.65 to 1.75 will do. The timber framing of the vent column, which should be diagonally braced all the way up, consists of four tapering pine poles at the four corners. The internal dimensions of the vent column are, at the bottom seven feet square, at the top, on a level with the cistern, five feet square. It is cased in the inside with weather-boards, painted white. These are better than tarred boards.

The lead work consists of cylinders four feet in diameter and six and one-half feet in length; including the flanges they are seven feet, which is the width of a sheet of lead. The full height of the column should be such as to enable it to contain forty-five feet depth of coke. It is represented in the drawing rather shorter than it ought to be. The three lower cylinders, or nineteen and a half feet of the length of the column, should be of lead, weighing twenty pounds to the square foot; the two next, or thirteen feet of the column of lead, weighing fourteen pounds to the square foot; and the two next, or the two highest cylinders of lead, weighing eight pounds to the square foot.

This apparatus, charged with lumps of coke, some very large, is much used and highly esteemed by some of the best makers of acid. On this account it is here shown in detail, the object being to give descriptions of the best existing apparatus, and the methods used by large manufacturers, irrespective of the plans thought better by individuals, but which cannot be considered as established in the trade. The accompanying plan has, however, several faults, which must not be overlooked. The massive leaden structure is expensive and inconveniently high. Its want of permanence is, however, the most serious evil, occasioning costly renewals and troublesome delays in the work. The acid, which is strongly charged with nitrous gas, and the electro-negative coke, coming in contact with the lead, causes its comparatively speedy destruction, and necessitates from time to time a total renewal of the column. To obviate these difficulties, a column of brick is sometimes placed inside the leaden one, and the interior of the brick column is heated and coated with pitch before the coke is put in. The objections to this plan are not so great as to the other. There is, however, a small, compact, and perfectly indestructible substitute, tested by several years' use, though it is not much known to acid manufacturers. It consists of two columns, three feet in diameter each, and about seven feet in height. The depth of the active condensing material within is equal to the height of the column. This consists of clean, rounded, purely silicious pebbles or coke, (but the former is preferable,) screened so as not to be smaller than one-third of an inch nor larger than two-thirds of an inch in diameter. Within these columns no timber framing is needed. The structure, pattern, and material are peculiar but simple. They have been made solely by Messrs. Cliff & Co., manufacturers of chemical ware, Lambeth, London, who usually have some in their ready-made stock.

THE CHIMNEY SHAFT.

If bricks are dear, the walls can be constructed about one-half the thickness here given. The form of the shaft is circular in section, and more conical and tapering than chimney shafts usually are. This is of great advantage, as much less care is necessary in preparing the foundation, for an inch of inequality in its settling counts it over less than if the base were smaller. There is also less liability of the structure set-

ting. It resists storms much better, and holds itself together without iron hoops when the acid fumes or other causes cause it to crack vertically. The size of the chimney at the top is no larger than is necessary for the free escape of the gases. This prevents the down currents of cold air when there are few fires at work, and consequently but little motion of air in the chimney. The form of the top of the chimney is such that the wind increases the draught instead of making it uncertain and variable, or even downward, as is often the case in gales of wind with plain-topped chimney shafts. The top is composed of fixed tronghs, radiating all around the orifice conically downwards at an angle of forty-five degrees, so that the wind striking against the top is carried upwards instead of glancing off sideways and "splitting," as it is termed, on the edge of the opening.

PLATE III.

PYRITES FURNACES.

The construction of the pyrites furnaces is shown on this plate by a general plan, on a scale of one to twenty-four; a vertical section through the middle of the furnace at right angles to the front, (cross section,) and a section through the middle, (a longitudinal section,) in a plane parallel to the front; and also a front view or elevation.

Many of the details of construction are explained upon the plate.

This construction of furnace is better adapted to rich Spanish ores (sulphide of iron with a little copper, and not much earthy matter) than to common poor pyrites, (sulphide of iron, with lime, silex, alumina, and frequently arsenic in quantities.) This kind of ore needs a larger furnace, a great mass of fire, and to be burned gently, so as not to flux it. The furnace should never be very red hot in any part of its interior, and the form should be different from that shown in these designs, and should either be cylindrical or enlarging downwards, instead of small at the bottom and enlarging upwards.

REMOVAL OF ASHES—CHARGING.

The ashes are ground out of the furnace by working the bars round and reversing the motion occasionally, so as to make room for the required charges. The charge is one and a half hundred weight (168 pounds) each hour; no more than this is to be put in at one time. The draught of the furnace should be properly regulated, so that it may burn at the required rate; the rate may be more or less than an hour's interval for each charge, but an hour causes good elimination of the sulphur; if a different rate is required, the frequency of the charge may be altered, but not the amount.

REGULATION OF THE DRAUGHT.

The draught of each of the furnaces in the row is regulated by a twelve-inch square tile placed over the nine-inch square hole in the top of the groined arch of the furnace. The position of the tile is changed by means of a rake inserted through the back door way of the nitre oven. The draught is also regulated by means of the ash-pit, by closing it more or less by a flap of sheet iron or by bricks or ashes. This is done partly to regulate the draught, but chiefly to retain the heat of the under side of the pyrites resting on the bars.

The mass is poked and lifted through the small doorway below to prevent its becoming agglomerated by fluxing, or so hard or compact as to impede the passage of air through it.

GRATE-BARS AND LINING OF INTERIOR.

The rests for the grate-bars are forty-eight inches long, five inches broad, and one inch thick, and are set on edge. They are perforated with holes three inches apart from center to center, and large enough to just receive bars one inch square. The parts of the interior most exposed to the fire are lined with fire bricks to a depth of from four and one and one-half to nine inches.

PLATE IV.

DETAILS OF SULPHUR FURNACES AND STEAMERS.

In this plate the sulphur pans are shown in plan and sections, together with the sliding door, and the details of the cast-iron front, and also the details of construction of the steamers and their covers.

SULPHUR PANS.

Figure 31 is a plan or vertical view of one of the sulphur pans, and Fig. 32 is a longitudinal section showing the construction of the front and back. Fig. 33, an elevation as viewed from behind, with a vertical cross section of the pan in the plane of the two screw bolts, six and one-fourth inches from the front of the pan.

STEAMERS.

A, B, and C, in Fig. 34, are cast-iron plates placed horizontally one over each sulphur furnace. Each plate supports a leaden steaming pan. E and F are cast-iron plates set on edge between A, B, and C to support the sheet lead forming the sides of the pan. These sides are folded over the top edges of the plates E F.

STEAMER COVERS.

The steamer covers are drawn to one-fourth of their actual size, together, also, with the brick division wall separating the pans.

CAST-IRON DOOR.

The cast-iron sliding door represented on this plate is intended for the furnaces, and is particularly referred to in the description annexed to Plate V ; it is shown in section in two directions.

PLATE V.

CAST-IRON WORK FOR COAL OR COKE BURNING FURNACES, AND FOR THE NITRE-POT OVENS.

CAST-IRON WORK OF THE FURNACES.

Figures 1 to 11, inclusive, show the details of construction of the cast-iron work of the furnaces. The sliding door is shown upon Plate IV. It is so formed that it will suit, without any alteration, all the furnaces throughout the works. It is here shown as adapted to the parallel fire-tiles at the sides, and to a dumb-plate below, as required for furnaces in the department for concentrating and rectifying the acid.

NITRE POT OVENS.

The details of the cast-iron work for the nitre-pot ovens are here shown in Fig. 17, 18, and 19. Figure 18 is a vertical section, longitudinally along a medial line. It shows the flue for the reception of the nitre pot.

NITRE POT.

Figures 26 to 30, inclusive, show different patterns of nitre pots.

The medium charge of nitre for the pot represented in Fig. 26 is four pounds. The medium charge of nitre for the pot represented in Fig. 28 is twenty pounds ; the greatest charge thirty pounds.

The proportion of acid to be used to every four pounds of brown commercial nitre, with the usual impurity and moisture, is 1.54 pints of sulphuric acid at 154° Tw., or specific gravity 1.770 ; this is the best strength. When this cannot be obtained, 1.58 pints of acid at eighty per cent. (*i. e.*, 142.4 Tw., specific gravity 1.712) may be used.

PLATE VI.

EVAPORATING PANS, STEAMERS, AND FURNACES.

In this plate the details of construction and placing of the evaporating pans or steamers is fully shown.

Figure 1 is a longitudinal section through the center of the bank along the line A A marked upon the plan. This shows the construction of the furnace, the ash pit, the pan at the bottom to hold water, and the

long flue leading under the eight pans or steamers placed side by side. Figures 2 and 2^a represent a pair of banks in plan. Figure 2 is a horizontal section. Figure 2^a represents the bank in a complete state, as seen from above. Figure 3 presents an elevation or external view of the front of the furnace, and also a section through pan or steamer No. 1, in the plane B B. It shows the interior of the fire place and ash pit. Figure 4 presents an external view of the back end of the furnace bank, with cross section of the flues, and a section in the plane C C, or through pan or steamer No. 9. Figure 5 is a vertical cross section at the middle of No. 3 steamer, with a further part of the bank, shown in oblique projection, in perspective view, with the point of distance very far removed, in order to show the form of one of the hand siphons and its position when in use.

REMARKS UPON THE FURNACES.

The furnace is very simple, but is adapted to economize fuel, and to consume smoke to a great extent when properly stoked. The surface of the fire-grate is made large enough to burn "brise," (sifted cinders,) or other poor kinds of fuel, while doing full work.

A flap of sheet iron should be hung against and cover the upper part of the entrance of the ash-pit, and be so adjusted as to cause a considerable proportion of the air to be drawn through the chinks which ought to be left in and around the door of the furnace. It is preferable to have the ash-pit closed from above, as described, than at the sides.

The bottoms of steamers, which are five feet by six feet, are not level, but slope two inches in the forty-eight and one-third feet toward the furnace; they also slope two inches in the six feet toward the outer sides of the pair of banks. Their sides are also inclined outwards three inches each from the perpendicular on the sides of the bank, and one and three-eighths inch on the sides next to the adjacent steamer.

The iron plates on which the steamers rest should be made of a single piece, one being placed under each steamer. The lower sides of these iron plates rest on small cast-iron wall plates leading to a small gutter, so arranged as to carry off the acid escaping by leakage, which would otherwise be lost, and by entering into the brick work gradually destroy it.

COVERS OF STEAMERS.

The covering boards are one inch in thickness, coated with the thinnest sheet lead, (two pounds per square foot.) They are supported at each end of the steamer by a frame resting on the brick work, and made of bar iron one inch square, likewise coated with lead. A sheet of thin lead hangs from these iron frames, to prevent draughts of air across the steamer. A narrow space is left between the edges of the lowest covering boards and the upper edges of the sides of the steamer, to allow a current of air to enter, which makes its exit at the top of the

cover, where, between the two edges of the cover, a wider space is left, sufficient for ventilation and for carrying off the watery vapor, but not so large as to allow the acid to become cooled by more air passing over it than will remove the vapor, or the heat to escape by radiation, as is the case to a very large extent when the steamers are left without covers.

The apparatus here described has been long in use, and has been found to be both economical, durable, and convenient. Bars instead of plates are used quite often under the coolest steamers. An economy of fuel is undoubtedly effected by this arrangement, not merely by the lead being exposed directly to the action of the heat, but also by the gases as they glide past being retained by the projecting bars. Steamers, however, supported in this way, are more liable to injury from careless treatment, and the arrangement is not to be recommended.

The pair of banks, such as represented, when in moderate work, can concentrate sulphuric acid from 115° Tw., or 1.575 sp. gr., to 154° Tw., or 1.770 sp. gr. It is then ready for rectifying in the platinum vessel, which gives 10,000 pounds of vitriol each twenty-four hours.

PLATE VII.

PLATINUM STILL, HAND SYPHON, AND STEAM JET.

PLATINUM STILL.

The still here represented is from the establishment of Johnson Matthey & Co., manufacturers of platinum, Hatton Garden, London. Two or more were exhibited in the case containing the platinum apparatus sent by this firm to the Exposition.

The body of the still is twenty-eight and one-half inches broad at the base and thirty-six inches at the widest part above. The total height from the bottom to the top of the hood is thirty-eight inches.

HAND SYPHONS.

These are of platinum, and one is shown in section sideways and as it appears from behind. The dimensions are given upon the plate. The figures are about one-fourth of the actual size.

These syphons are capable of being filled or emptied without the usual trouble, and of being carried about without losing their charge. They are more simple than a cupped syphon, and draw from the bottom of the steamer. They deliver freely, and while in use in liquors evolving gases (the steamers sometimes evolve sulphurous and nitrous gas) these syphons, each having an air chamber, retain their charge a much longer time than an ordinary syphon can under similar conditions.

For connecting steamers in the hotter part of the bank, the syphons

need not be made with the air chamber, unless the acid is frequently of very bad quality, containing much gas. The smallest depth of liquor in which this syphon can be charged is six and one-half inches.

STEAM JET FOR CHAMBERS.

Steam jets are made of chemical stone-ware. Those manufactured by the Messrs. Cliff, at the Imperial Potteries, Lambeth, London, are porous, baked at a heat below vitrification, and are not glazed. These withstand the effect of acid gases and the sudden heat of steam, and will maintain a uniform jet of high-pressure steam, which can be regulated by chipping off the indented end of the jet. This jet-hole does not clog or enlarge as with a leaden jet. The conical exterior insures a close fit into a smooth circular hole in the sheet lead forming the top of the chamber, and without enlarging the hole by wedging too tightly into it.

APPENDIX.

COLORING MATTERS DERIVED FROM COAL TAR.

EXTRACT FROM THE REPORT OF DR. A. W. HOFMANN.

"This is no longer an age in which an industry requires many years for its creation, and still longer time for its development and expansion.

"Jealously guarding the processes employed, hiding with care the raw materials used, a manufacturing process formerly was hid in an obscurity which had the effect of confining a profitable monopoly to the country where it was first established. The privileges conceded by the rulers, a host of legislative enactments; general ignorance, and the special organization of labor, all tended, at a period anterior to 1789, to favor this result.

"In our days, a useful discovery is scarcely made, or a happy application of one found out, before it is published, described in the scientific journals or other technical periodicals, and especially in the specifications of patents. It then becomes the starting-point of a thousand researches and new experiments, entered into by the philosopher in the hope of advancing scientific progress, and by the manufacturer with the expectation of reaping a material benefit. From these multiplied and diverse efforts, these incessant labors of an army of workers, arises an industry which has no sooner sprung into existence than it becomes important and prosperous. Moreover, it is not only in the land of its birth where its development takes place; it extends rapidly in foreign countries, so that it not unfrequently happens that the place where the discovery has originated is distanced in the applications of it by neighboring states. The ocean itself is no longer a barrier between the nations which it separates. New York, in an industrial sense, is now a neighbor of London, Paris, and the German centers of industry.

"The history of the artificial coloring matters derived from coal abounds in illustrations of this. It only dates from the end of 1856, and yet what success it had achieved in the Exhibition of 1862!

"From that date, owing to the number, variety, beauty, and value of its products, and from the large scale on which it was carried on, it might rank with the largest industries. In 1862 the value of these manufactures had risen from nothing to ten millions of francs; at the present day this sum is trebled, and still the products are much cheaper

than they were before. Indeed, the improvements successively introduced into the manufacture of the tinctorial products derived from coal have had the result not only of rendering them more beautiful, but at the same time of reducing their cost in such a manner that aniline colors can successfully compete in price with any other coloring matter of equal tinctorial power; so that if they were formerly purchased on account of the unexampled brilliancy of their tints, they will retain their importance owing to the low price at which they can be produced.

“Among the coloring matters which were already known in 1862, some have now become true *raw materials*, from which are produced other coloring matters equally beautiful, equally rich, and of no less importance than those from which they have sprung.

“Thus, rosaniline has become the parent of a whole series of colors, and last of all of a green. The gamut of coloring matters derived from aniline is now complete; we have red, orange, yellow, green, blue, indigo, and violet.

“Are we not justified in saying that the manufacture of artificial coloring matters, in spite of the improvements of which it is yet capable, in spite of the discoveries which will yet enrich it, and scarcely ten years old, has emerged from the state of infancy, and become one of the most important industries of the age?

“But if the development of this new branch of manufacture has attained so high a point in so limited a time, its publication and diffusion through the industrial and commercial world have advanced with still greater rapidity. The first of the aniline dyes in order of date is mauveine. This was discovered in the month of August, 1856, by Mr. W. H. Perkin. Whilst the inventor, young, and of ample resources, remained for nearly two whole years before he could carry out his invention on a large scale, and strove against the difficulties which beset the introduction of all new discoveries, several French manufacturers produced mauveine immediately, and on a large scale, by the actual process (or but slightly modified) which was revealed to them by the English patent. One who only considered the state of the industry at this time in the two countries, would have said that the invention belonged to France, and had only been imported into England. From France it almost at once spread to Germany.

“In 1859 aniline red was produced. Scarcely three months after its production was commenced at Lyons it was transplanted to Mulhouse; then crossing the Channel, it became established in England, at London, Coventry, and Glasgow, and was not long before it was taken up in Germany.

“Aniline blue first appeared in 1860. Less than a year afterwards it took ten manufactories in Germany, England, Italy, and Switzerland to produce this new material.

“While the manufacture of aniline colors thus became European, their consumption spread still further; and now could be observed this

unique fact in the history of commerce: the West supplied the East with coloring matters, sending its artificial dyes to the confines of the globe, to China, to Japan, to America, and the Indies—to those favored climes which up to the present time had supplied the manufactories of Europe with tinctorial products. This was a veritable revolution. Chemistry, victorious, dispossessed the sun of a monopoly which it had hitherto always enjoyed; at the beginning of this century, when mythological language was in vogue, it would have been said that Minerva had triumphed over Apollo.

“But it was not sufficient to extract colors from tar and send them to China; it was necessary to secure a market for them and get their acceptance; and now occurred a circumstance characteristic of this epoch. In order to apply these colors, the processes being altogether different from those followed by the Chinese, and their employment requiring the assistance of substances which were unknown to them, it was necessary to change at the same time their tinctorial substances, their solvents, and their mordants—in a word, to undertake the education of the Chinese dyers. This difficulty did not for a moment stop the European manufacturer; he sent to China and Japan not only the workmen who should teach his customers the way to apply the colors with which he supplied them, but also the chemical products necessary for their manipulation, such as sulphuric acid and absolute alcohol, which were before unknown to them. Thus arose considerable dealings with the East, the quantities sold by European manufacturers in 1864, 1865, and 1866 amounting to several millions of francs.

“The Universal Exhibition of 1867 shows considerable progress in all branches of the manufacture of artificial colors since 1862. It should here be noted that the year of the English Exhibition was itself one of the most fertile in discoveries and improvements.

“Almost immediately after its close there appeared aniline green, the violets of methyllic and ethylic rosaniline, and aniline black, and at the same time science was able to dispel the darkness which had hitherto enveloped the production of the new coloring matters. If we wished to generalize, we should say that exhibitions are not only of value in registering acquired discoveries, but still more of inducing and hastening the birth of new inventions. However this may be, we may here tabulate the coloring matters mentioned in the reports of the Exhibition of 1862:

- Pieric acid.
- Isopurpurate of potash.
- Mauveine and its salts.
- Rosaniline and its salts.
- Rosaniline blue.
- Rosaniline violet.
- Chrysanline, (Phosphine.)
- Peonine.

Azline.
Emeraldine.
Viridine.
Azurine.
Pseudo-alizarine.

“Some of these colors have disappeared from commerce, if, indeed, it is certain they were ever introduced; these are emeraldine, viridine, azurine, and pseudo-alizarine. The consumption of mauveine has diminished considerably, as well as that of the rosaniline violets; but, on the other hand, the importance of rosaniline and of triphenyllic rosaniline blue has greatly extended. At that time aniline black only existed in theory, now it is one of the most valuable of this class of colors.

“The following is a list of the coloring matters which, since 1862, have entered, or are about to enter, into commerce, and which figured in the Exhibition of 1867:

Aniline green from aldehyd.
Methylic and ethylic rosaniline violets.
Aniline green from iodide of methyl.
Aniline maroon.
Aniline gray.
Aniline black.
Mauvaniline.
Diphenylamine blue.
Chrysotolnidine.
Naphthalic red, (salts of chloroxynaphthalic acid.)
Naphthalic yellow, (binitro-naphthol.)

“Among these latter substances many are of considerable importance, such as the new greens, the violets, and aniline black.

“But if new colors have been discovered, the improvement of the old ones has not been neglected; their price has been lowered; their extreme purity and beauty, which at the date of the 1862 Exhibition were exceptional qualities, have now become matters of ordinary production; and the healthiness of the manufacturing processes has been considerably ameliorated.

“Corresponding improvements have been effected in the industry of the raw material. In 1862 a large quantity of coal tar was completely lost for the manufacture of artificial coloring matters; although for some time it was collected in certain works, at St. Etienne, for example, thanks to the care and processes of MM. Pauwels and Knab. The problem consisted in transforming the ordinary coke-ovens into gas retorts, which while producing the same quality of coke admitted of the collection of the tar and gas; the latter serving to heat the ovens themselves. These apparatus, which the limited scope of our report prevents us from describing, are becoming more generally adopted; they have already exercised a notable influence on the price of the products.

distillation of coal, and especially on the light oils, although the tar is far from being collected in a complete manner.

"In France three millions of tons of coal are carbonized annually to supply coke for metallurgical purposes. When the process of MM. Panwels and Knab¹ is more generally adopted there will be collected from this, one hundred and twenty-five or one hundred and thirty millions of kilograms of tar, which would yield two or three millions of kilograms of light hydrocarbons. It may therefore be predicted that the price of benzols will fall still more, and that consequently the cost of coloring matters derived from it will be reduced. These prices are at the present time from seventy to eighty centimes the kilogram for benzol; in 1862 it was worth three or four francs the kilogram. Aniline, which then cost from twelve to eighteen francs, is now worth two and one-fourth francs, or three and one-half francs at the maximum. Crystallized hydrochlorate of rosaniline has fallen from two hundred and fifty to three hundred francs to twenty-five and thirty francs. The blue which was formerly sold at five hundred francs is now offered at one hundred francs, and inferior qualities cost only thirty or forty francs. These figures prove in a most convincing manner the enormous progress realized by the aniline color industry since 1862.

"This reduction in price of the aniline colors is such that all manufacturers who use coloring matters have found it worth while to replace their former tinctorial products by these artificial colors.

"Besides this, the employment of these products has greatly simplified the formerly very complicated and costly operations and processes of dyeing, so much so that an apprentice can now obtain as good shades as a skilled workman; this facility of application has certainly not less contributed to the success of the coal tar coloring matters, than the richness and variety of their shades.

"The employment of these magnificent coloring matters is not confined to dyeing and calico printing. They are utilized in many other industries. Their different applications, the most important of which we shall rapidly glance over at the end of this report, have also contributed to their development, although they only consume a comparatively small amount of these coloring matters.

"The progress which we are about to record in the industry of the coal tar colors shows, in fact, that the probable development of the aniline colors and their economic and commercial results, foreseen by the Reporter² in 1852, are to-day accomplished facts. Everything, therefore, leads one to imagine that ultimately the natural will yield entirely to the artificial coloring matters.

"This revolution, the influence of which will be most important, since it will liberate for the production of food many lands now employed in

¹ See *Chimie*, by Pelouze and Fremy, vol. ii., p. 884. The apparatus of MM. Knab also figure in the exhibition of mines of the Loire.

² National Exhibition of 1862. Reports of the juries, class 2, section A, p. 120.

industrial operations, would already have taken place if the artificial colors hitherto discovered were as solid as their rivals. Less fugitive than when first prepared, owing to the greater state of purity in which they are now obtained, they are still too dear to enter largely into the dyeing of cloth and other textures used for household purposes. On reviewing the history of coloring matters in general, we may be permitted to hope that this defect of stability will soon disappear under the combined efforts of science and industry."

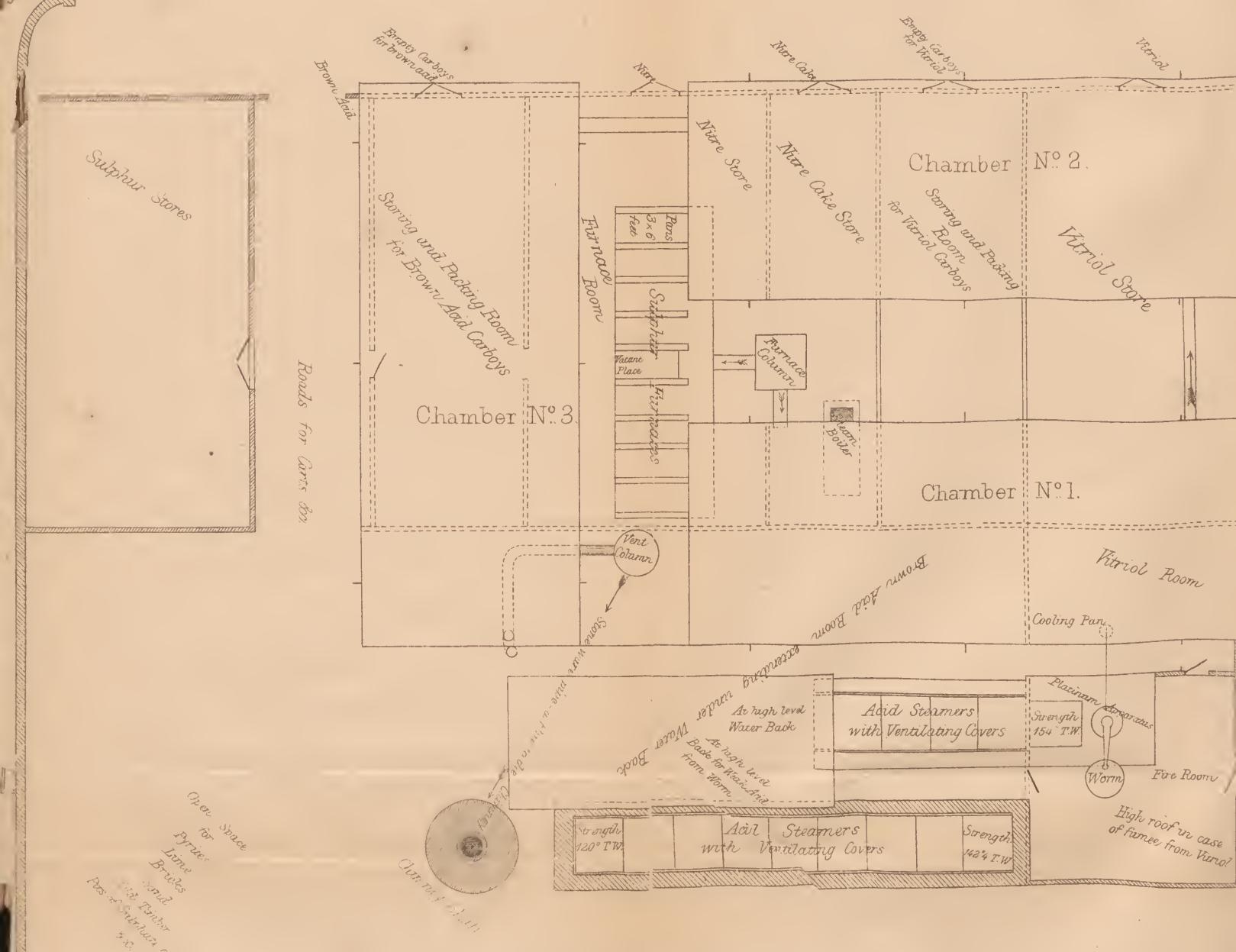


Shed
for
various
purposes

GENERAL PLAN OF VITRIOL WORKS.

Scale $\frac{1}{16}$ in. to 1 foot.

0 10 20 30 40



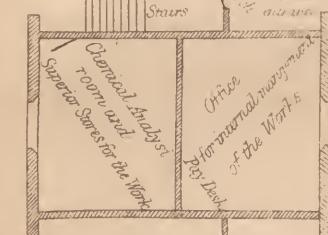
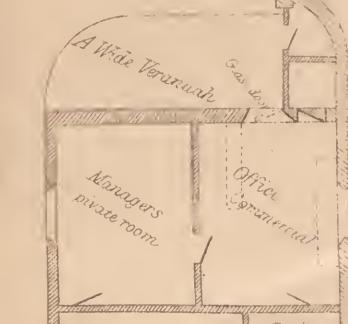
Ashes & cinders for being sifted

Timber Stores in open Air

Open Space
for
Bricks
Bones
Dust
and
Fistulas
of sand
and
ash

The Upper floor
is welding and forage
on lower floor

Table
Wagon House
and
Table



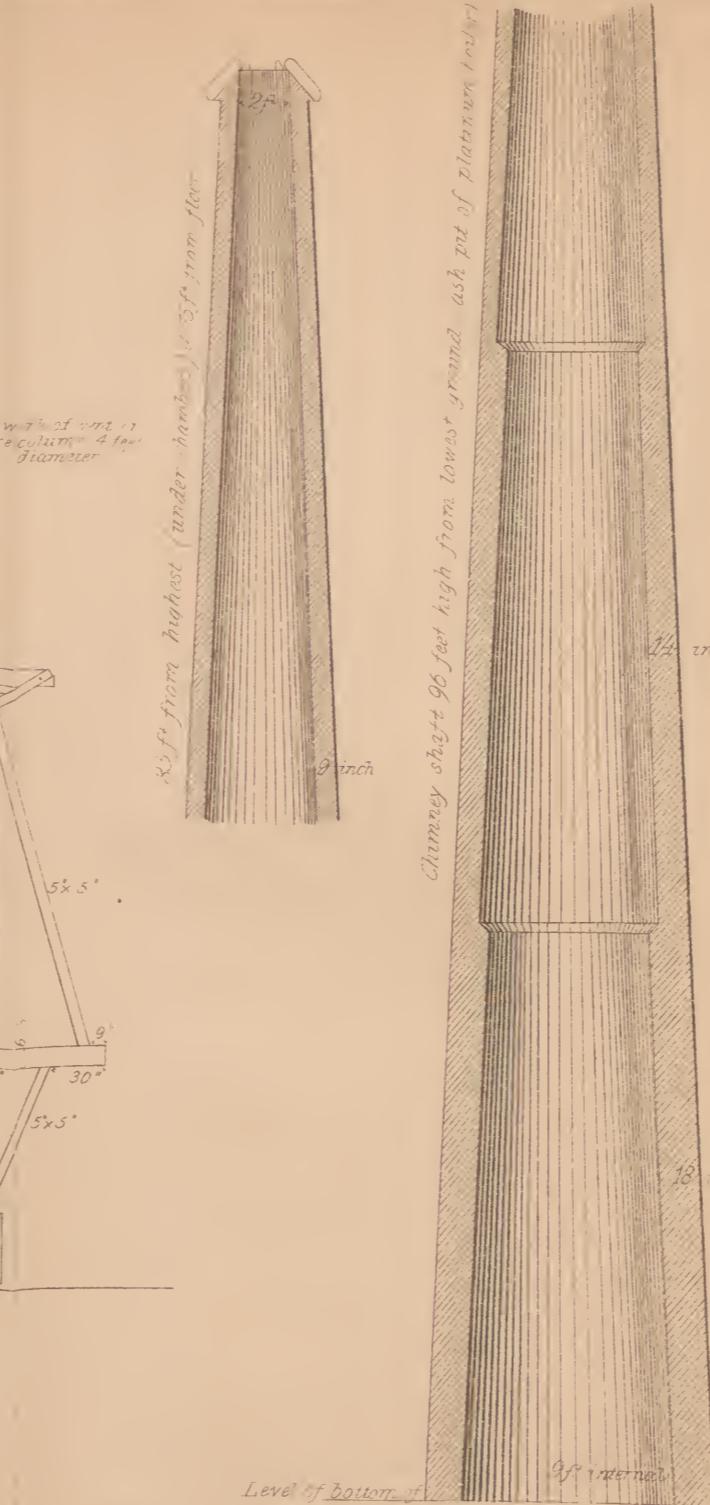
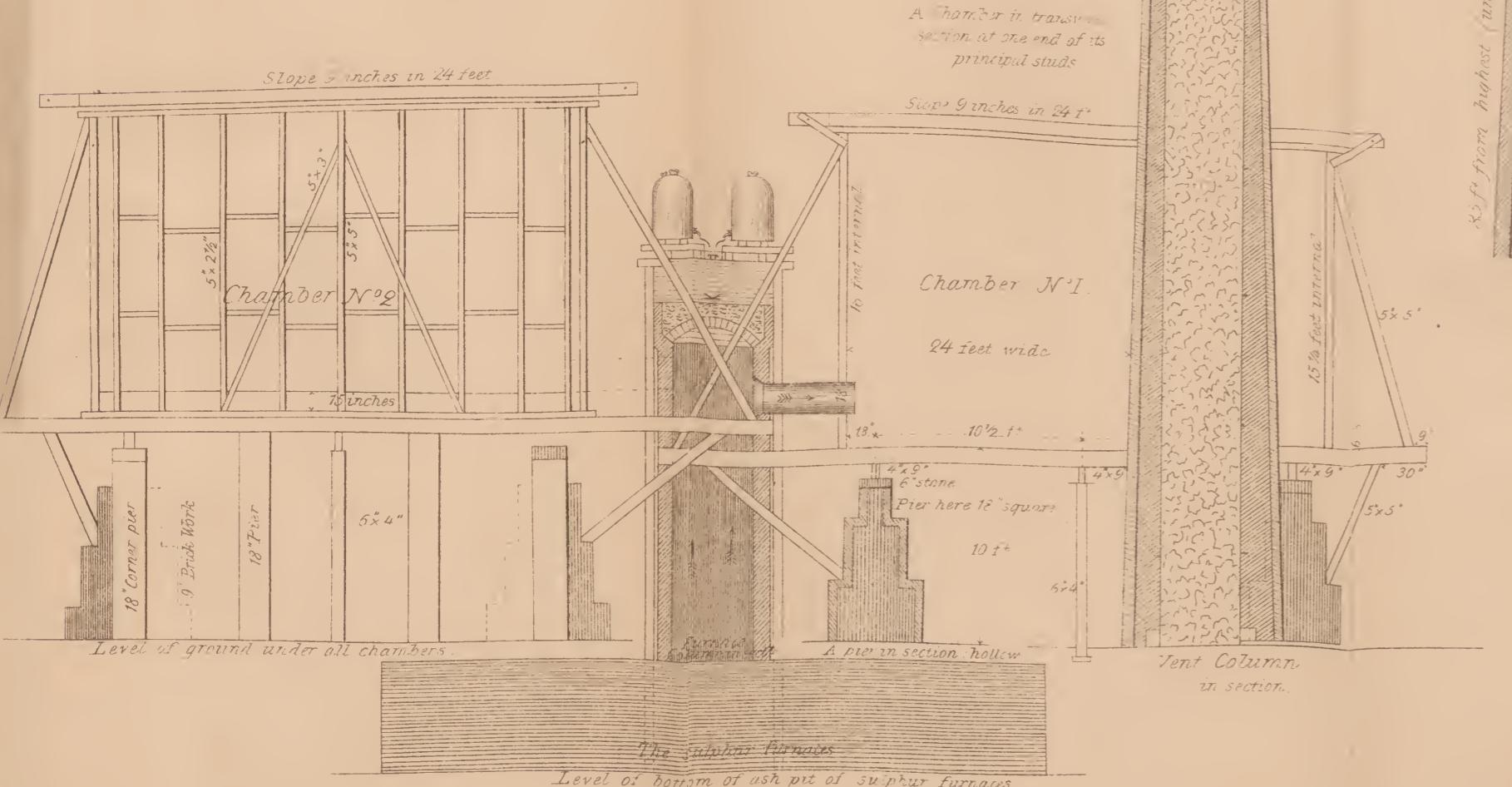
A Second floor over all these
contains domestic apartment

Coal Store
in open air



LEVELS AND SECTIONS,
IN DETAIL OF
VITRIOL WORKS.

" of one inch to one foot.



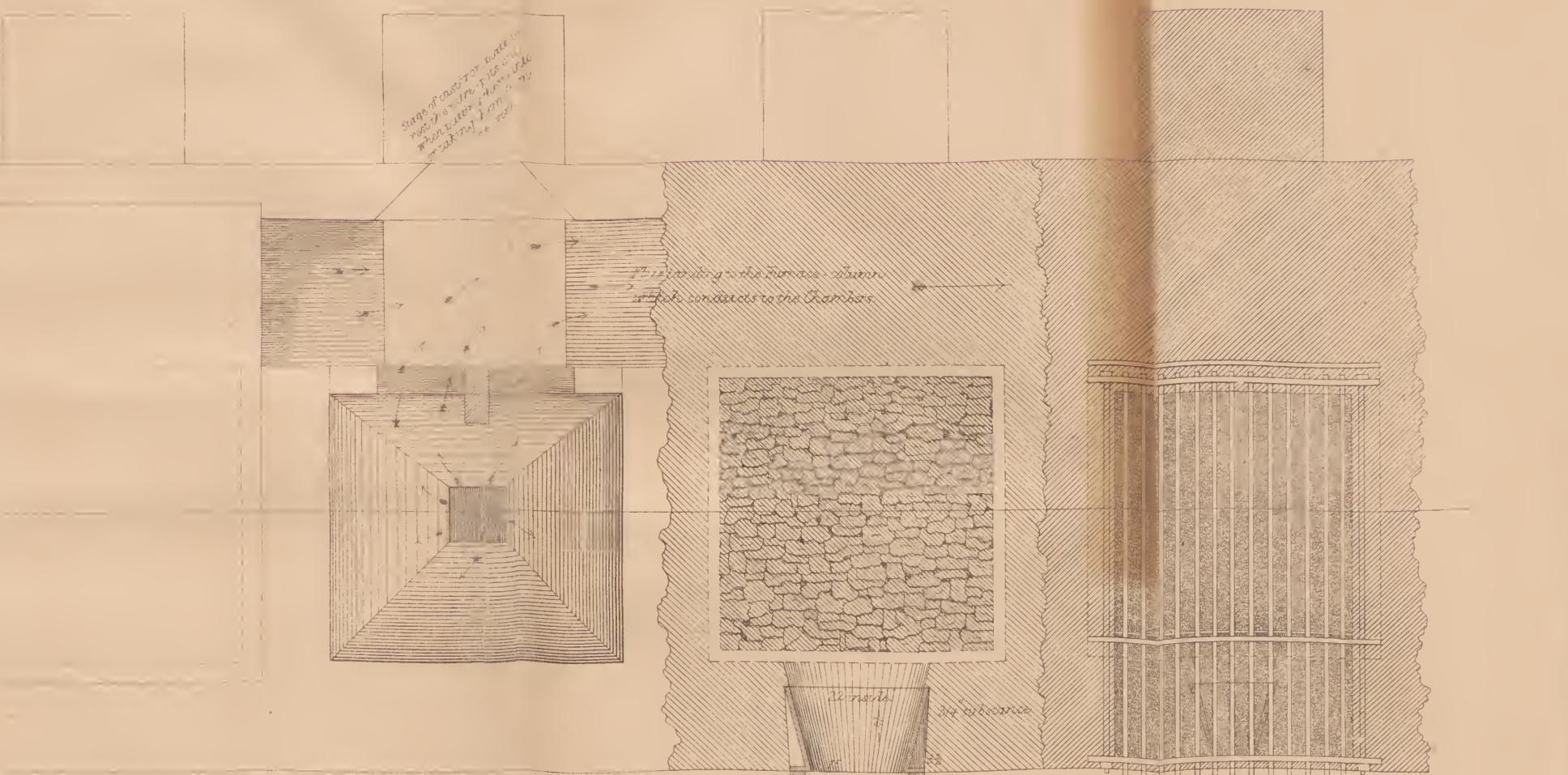
WHITE'S FURNACES.

W.M. above over all
inner and its framework removed.

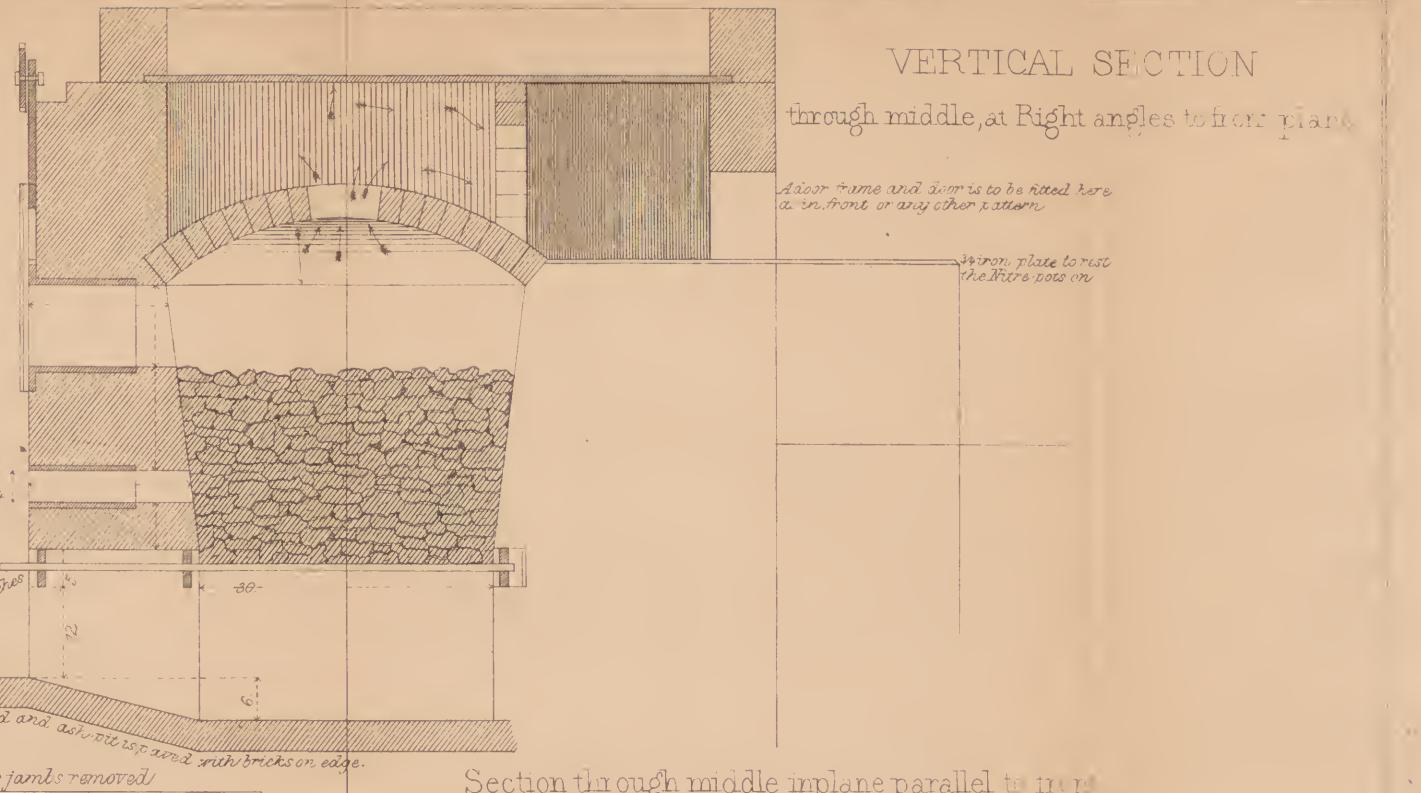
without the iron plate.

Section of levee in upper part of river way. Section a

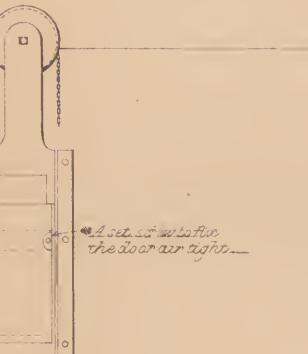
lever of the fire bar.



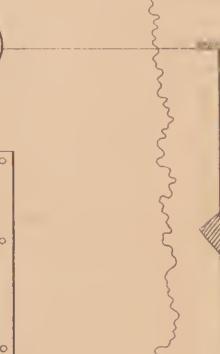
of Feet 1:24.



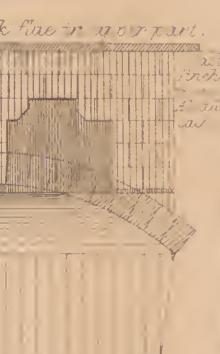
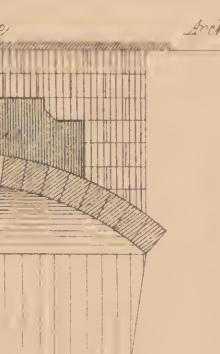
ENT VIEW

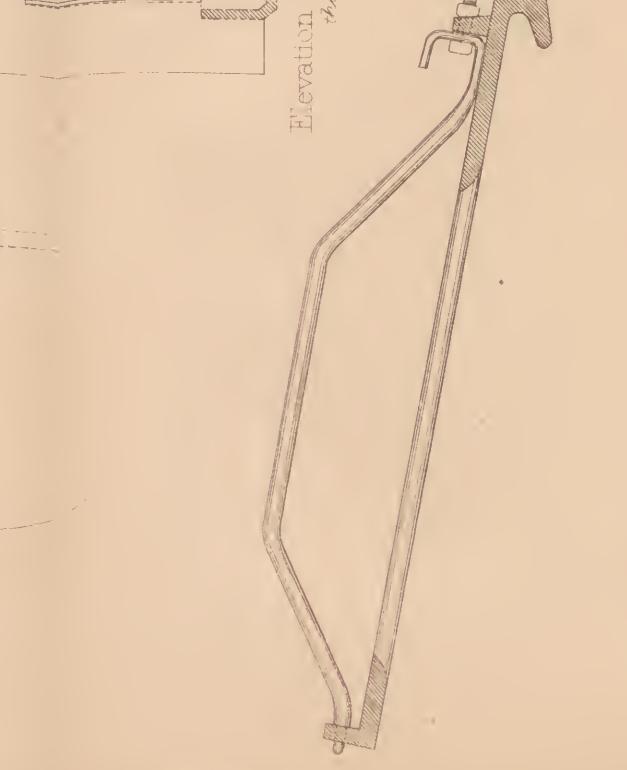
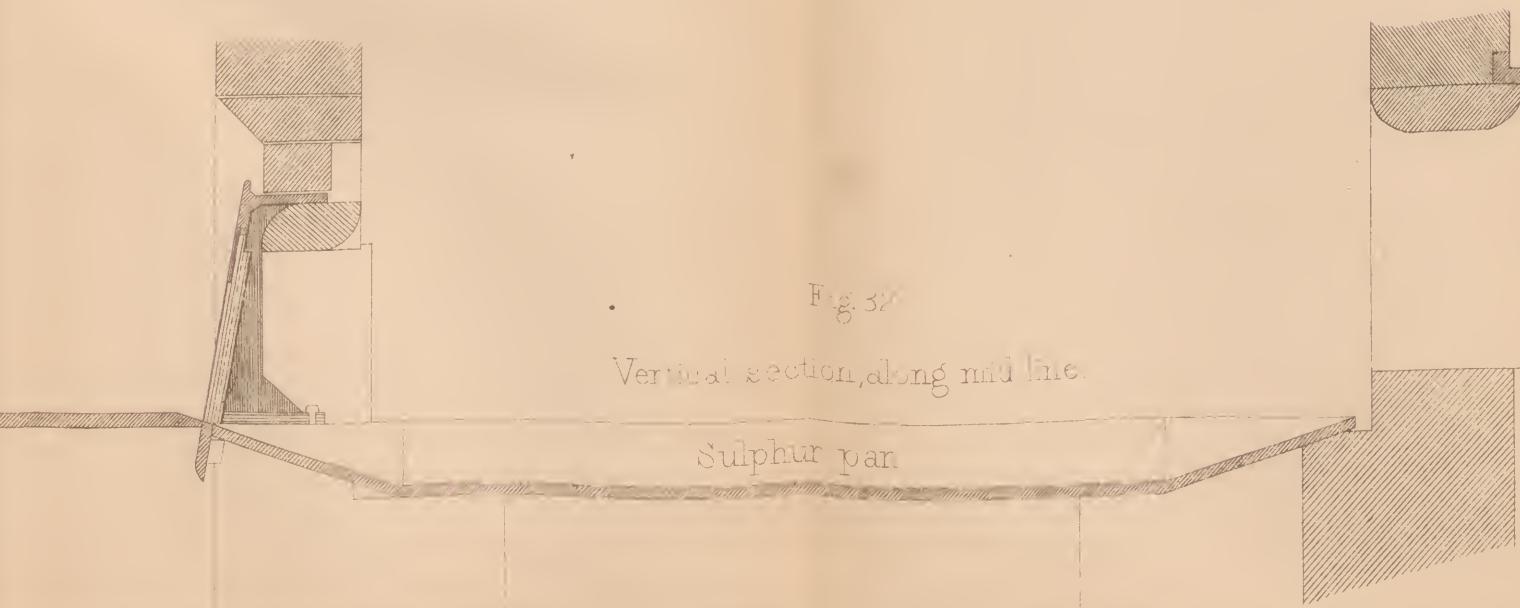
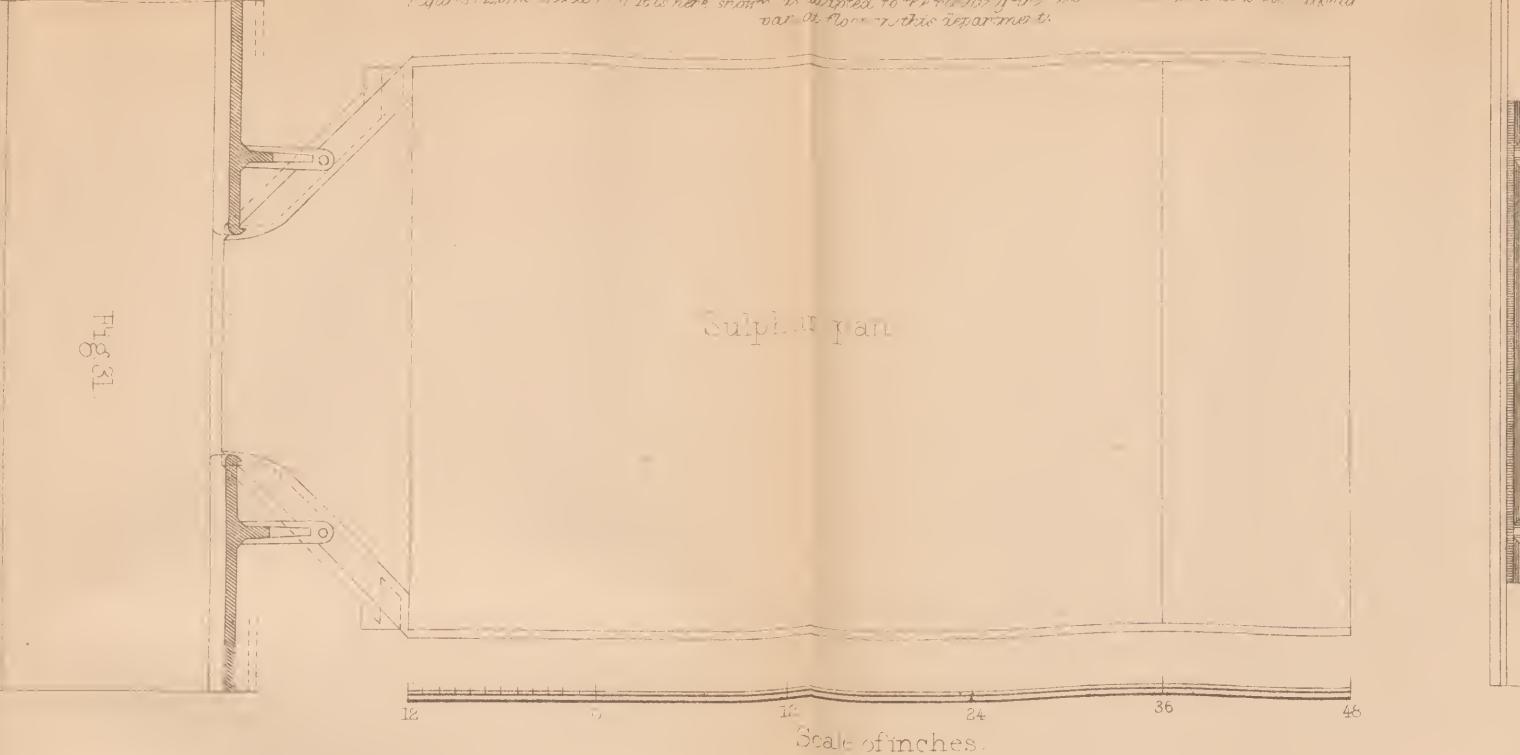


A technical diagram of a magnetic core. It features a rectangular base with a central rectangular cutout. A vertical magnetic path is shown as a line extending upwards from the top edge of this cutout. A circular air gap is located at the top of the core. A small diamond-shaped component is positioned at the top edge of the air gap. A horizontal line extends from the left side of the core towards the top air gap.

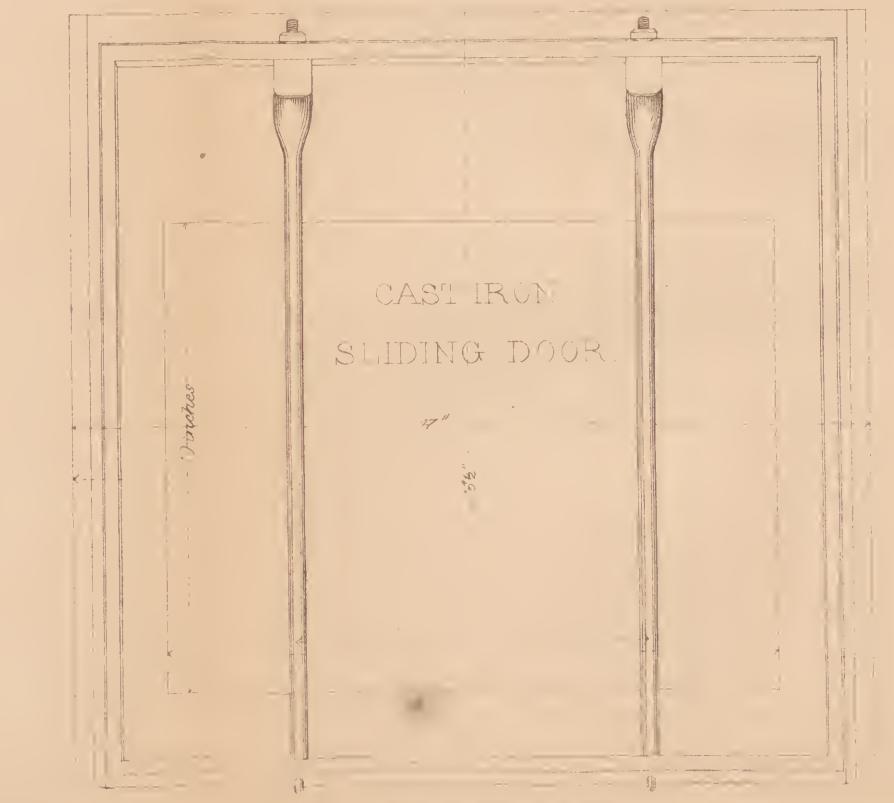


A detailed illustration of a birdcage. The cage is made of vertical wooden slats and features a horizontal perch in the center. A small, colorful bird is perched on the right side of the perch. The background is a plain, light color.

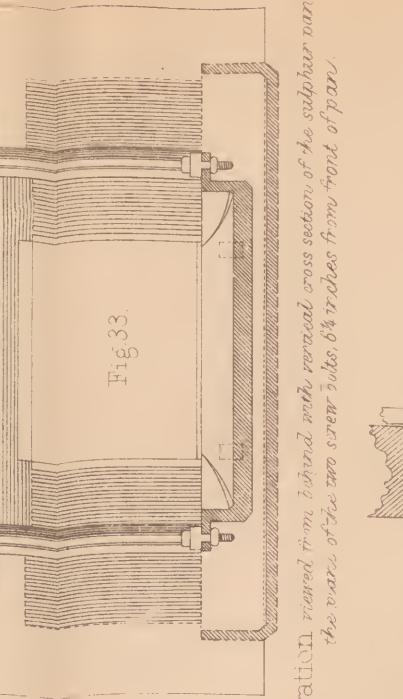




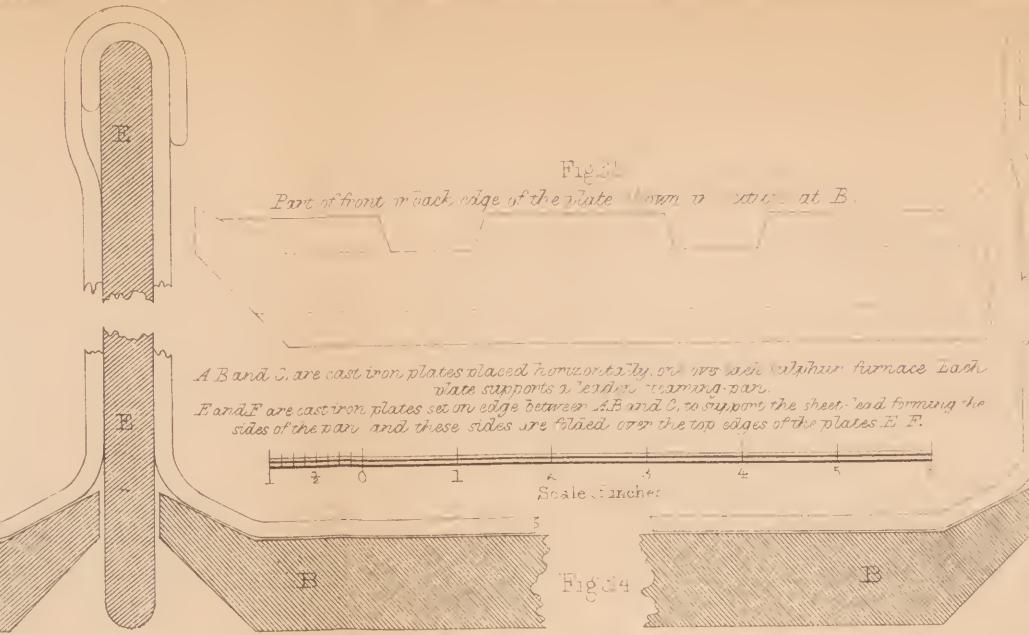
CAST IRON
SLIDING DOOR.



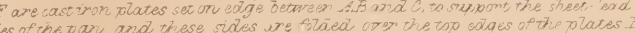
Vertical section, in a plane across the middle part of a sulphur-furnace



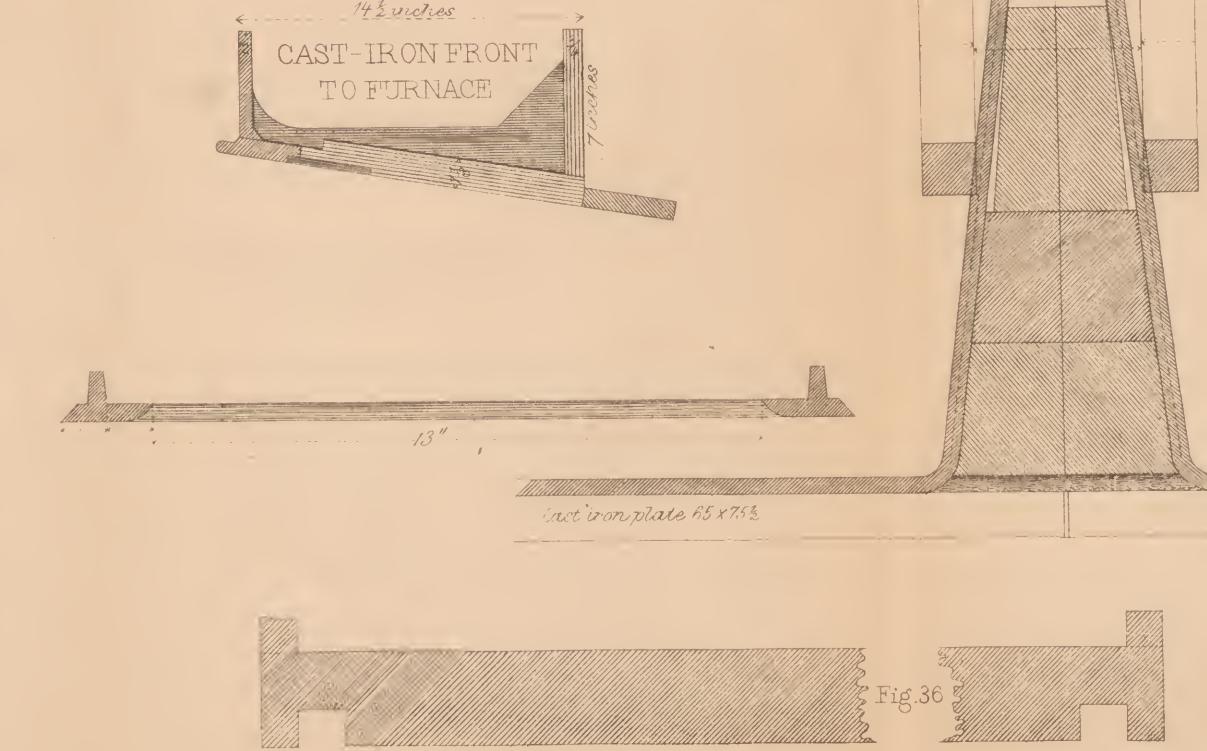
A detailed technical drawing of a mechanical assembly, likely a valve or fitting, showing internal parts like a seat and a stem. The drawing is labeled 'A' at the top right.



A and C are cast iron plates placed horizontally on the side sulphur furnace. Each plate supports a leaden ramming bar. E and F are cast iron plates set on edge between A, B and C to support the sheet lead forming the sides of the bar. and these sides are folded over the top edges of the plates E, F.



Scale, inches



The plate B, in section, in a vertical plane at right angles to the section shown in Fig. 34 here
is from back to front of a sulphur-furnace.

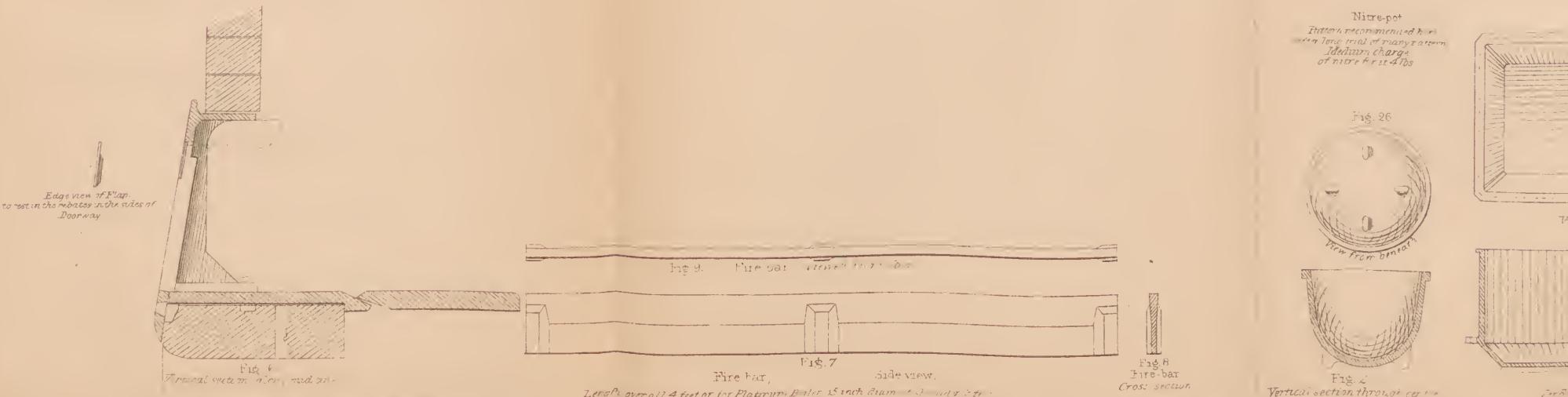
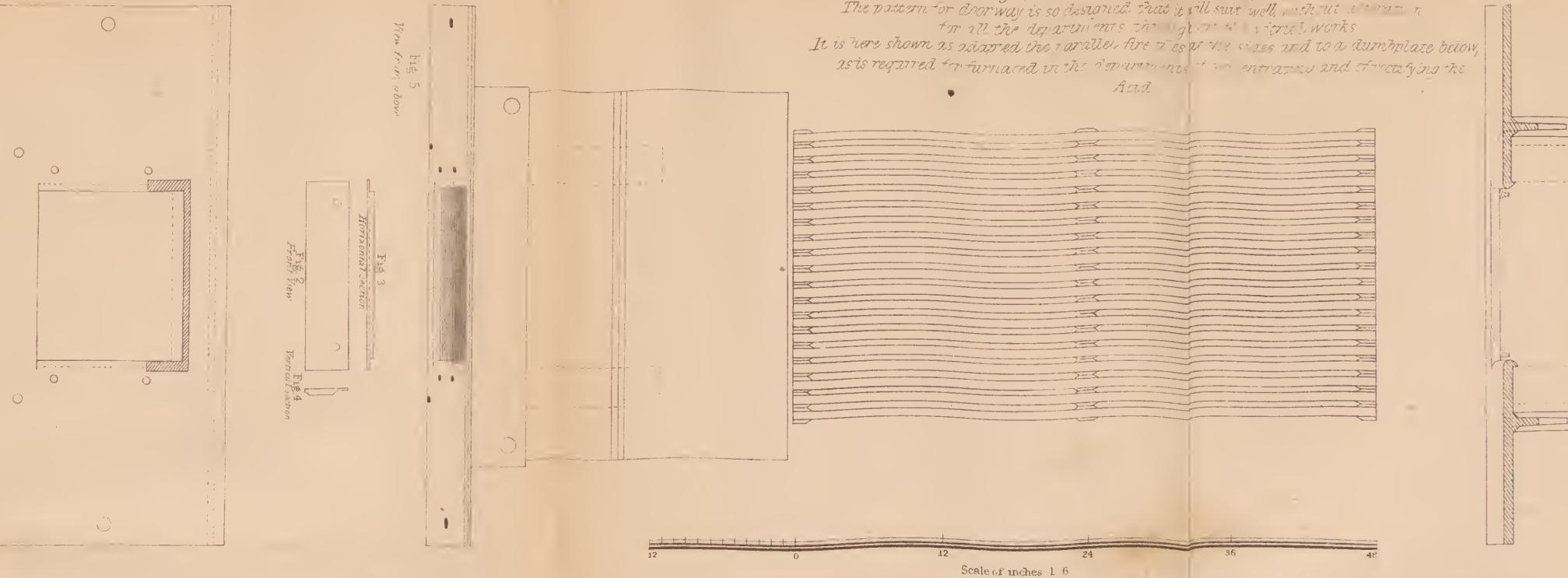
STEAMERS AND COVERS DETAIL

$\frac{1}{4}$ ACTUAL S

of the brick division-wall between any two steam

ON WORK

FOR COKE-BURNING FURNACES



CAST IRON WO

FOR THE NITRE POT

PLATINUM STILE

for v

Concentration of Sulphuric Acid

HAND SYPHONIC
for Scanners &c.
 $\frac{1}{4}$ Avo. Pz.

